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WAR DEPARTMENT

U.S. Dept of Army

TECHNICAL MANUAL



SHEET METAL WORK, BODY, FENDER
AND RADIATOR REPAIRS

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SHEET METAL WORK, BODY, FENDER, AND RADIATOR REPAIRS

Prepared under direction of
The Quartermaster General

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SECTION I

GENERAL

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General	1
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1. **General.**—*a. Repairman's job.*—(1) Sheet metal work and repair of motor vehicle bodies, fenders, and radiators are important functions of heavy maintenance units. Sheet metal parts such as the body, fenders, hood, fuel tank, radiator shell, and head lamps may be damaged by collisions. The radiator proper, that is, the core, the upper and lower tanks, fittings, and supports may be damaged by strain and vibration in regular service or by negligence, as well as by collision. To correct damages of this type is the repairman's job.

(2) This manual does not attempt to solve all the difficulties of sheet metal and radiator work, but it gives basic methods which can be adapted to practically all kinds of jobs.

b. Repairman's knowledge.—(1) To repair any article satisfactorily, a thorough understanding of its function and construction and a knowledge of the materials of which it is made are necessary.

(2) Know the uses and limitations of the tools and machinery. Like everything else, a machine or tool works better when used as it was intended to be used, and when kept in good condition. Even when using the most up-to-date tools, a poorly informed workman is a bad match for an educated mechanic using the crudest equipment.

(3) Study the damage in an automotive unit before going to work on it, to determine whether the unit can more economically be repaired or replaced. It is a poor policy to waste time on a part that has no further value. If a repair seems advisable, determine in advance how best to get at the part and what tools are required.

2. Sheet metal.—*a. Kinds.*—A wide variety of sheet metal is used in motor vehicles, including iron, steel, brass, copper, aluminum, and various plated sheets. The plated metals are terne plate (lead-coated iron) used for fuel tanks; silver-plated brass for lamp reflectors; and nickel or chromium plate sometimes used on administrative vehicles for headlights, radiator shells, and grilles. Bodies and fenders are usually sheet iron.

b. Sizes.—Sheets of different metals are rolled in stock sizes and thicknesses. The length and breadth are almost universally given in inches and the thickness usually by gage. This use of gages leads to confusion, as different mills use different gages and even the same mill may use different gages on different metals. For example, a No. 10 sheet of copper, measured on a "Stubbs" gage, is 0.134 inch thick; No. 10 sheet iron on the U. S. standard gage is 0.141 inch thick, and No. 10 zinc is only 0.020 inch.

c. Repairs.—Methods of repair are soldering, brazing, welding, stretching, and patching.

3. Radiator.—*a. Driver's responsibility.*—The radiator does the important job of cooling the engine and therefore must be kept in proper working condition. Every driver should clean or flush the entire cooling system at least twice a year (preferably autumn and spring) with a solution that will loosen and remove rust, lime, or grease deposits that clog the system or impair its efficiency. However, troubles may develop which are outside the scope of the first echelon. Eliminating these is the concern of the radiator repairman.

b. Causes of radiator failures.—(1) Freezing causes a large number of leaky radiators. To illustrate the enormous expansive power of freezing water, imagine a steel ball 6 inches in diameter, solid except for a cavity filled with 1 drop of water. If this drop freezes, the ball will break.

(2) Vigorous shocks, vibrations, and stresses weaken any radiator, but particularly a honeycomb type, which has large soldered surfaces. This is especially true if the radiator is improperly mounted or supported. Shocks, vibrations, and stresses are often caused by high engine speed, impacts, undue twisting and bending due to rough roads, or expansion and contraction of metal when heated and cooled.

Recently developed radiators have fewer soldered seams and less leakage trouble.

(3) Corrosion is the worst enemy of radiators. The simplest form is uniform corrosion which evenly reduces the diameter of the water passages. If the water is hard, a uniform layer of lime will also clog the passages. These conditions are usually unnoticed. Water passages may be pitted or etched with small conical depressions located side by side, or with small round holes cut by dezincification. The points where the metal expands and contracts are particularly liable to corrode. Cleaners, rust preventives, and antifreeze solutions that are too strong or wrongly applied, will also damage radiators.

4. Characteristics of materials.—*a.* Copper is an excellent conductor of heat and is a favorite metal for constructing tubular radiator cores. Unlike steel, it is annealed or softened by heating and sudden cooling, whereas vibration, hammering, rolling, or bending hardens it. Copper surfaces, like those of all other metals, must be tinned before soldering, because solder adheres to them poorly. Muriatic (hydrochloric) acid is usually employed as a cleaner, because it easily removes scale, rust, and other deposits that may adhere to copper. However, the acid, as well as the copper article, should be cold when cleaning, otherwise the copper will be attacked by the acid.

b. Brass is a mixture of copper and zinc and is another good heat conductor used extensively in radiator cores, tanks, and fittings. Its ability to withstand vibration is greatest when annealed by the same procedure as copper. Bend it only when it is cold, as hot-worked brass becomes brittle and breaks easily. It is more readily attacked by muriatic acid than copper.

c. Steel or iron is used in the construction of cast radiators and fittings. Bodies, fenders, fuel tanks, radiator shells, and brackets of motor vehicles are made from sheet steel, which is invariably terne plate (lead-coated).

d. Solder is a mixture of tin and lead, used to unite or seal the joints between copper, brass, and iron, as glue binds pieces of wood together. Commercial solder, sometimes called half-and-half because it is about 50 percent tin and 50 percent lead, has the greatest "sticking" strength, but solder with more tin than lead works noticeably faster. If a torch is used instead of a soldering copper, this difference in speed is unnoticeable. Softer solder has greater ability to withstand vibration in radiators, which offsets the better working quality of high-tin mixtures. Some solders are flux-filled (see par.

4e) to insure and hasten the soldering process. Solder is obtainable in spooled wire or in bars about 10 inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inch thick.

(1) Soldering mixtures are easily prepared. Melt the tin in a clay crucible, add lead, and stir the mixture until it has combined perfectly. Inadequate mixing produces solder which has a wide range of melting temperatures and consequently joins surfaces poorly. Only when the two metals are thoroughly melted and well mixed, should they be allowed to cool. Then pour the mixture into an iron mold about $\frac{1}{2}$ inch deep and 10 inches long. The melting point of this mixture varies inversely with the amount of tin (up to 70 percent).

(2) To insure uniform working properties and greatest life, a tin-lead solder must be pure. The presence of certain other metals even in very small amounts seriously reduces its ability to withstand strain, vibration, expansion, contraction, shock, and corrosion.

e. Flux is a chemical solution used to remove the oxide which forms upon any metal surface exposed to air. The ideal flux also remains as a film on the surface, preventing further oxidation. Applied to a seam or joint after cleaning, it assists solder or other filler metal to flow in and tightly seal the joint. Unless the filler fuses to the metal, the repair is useless.

(1) A common flux for soldering is "cut acid," a zinc chloride salt solution, produced by allowing muriatic (hydrochloric) acid to eat all the zinc it will consume. To this solution an equal quantity of clean water should be added.

(2) Borax is employed as a flux for all brazing. Where brazing is done on a large scale, boric acid is used more than ordinary borax, as it is more economical and can be obtained in granular form.

f. Paint is applied primarily as a finishing touch to the repair job. Any paint on a radiator core reduces its cooling efficiency. Therefore, a paint, never a gloss paint, that is not heat insulating should be used, preferably lampblack mixed with japan dryer and turpentine. This dries quickly to a flat black surface.

5. Glossary.—For purposes of clarity and uniformity, certain terms used in this manual are defined as follows:

Acetylene.—A colorless, inflammable, hydrocarbon gas (C_2H_2) with a distinctive odor; usually formed by the action of water on calcium carbide.

Aline (align).—To put the structural parts of an assembly in their proper relative positions.

Alinement.—Act of alining, or state of being perfectly alined.

Alloy.—A substance composed of two or more metals intimately united, with characteristics different from those of its ingredients.

- Arc*.—Part of the circumference of a circle; also, path or action of electric spark between two electrodes. (*See Welding.*)
- Bead*.—A rounded ridge rolled or stamped in sheet metal to strengthen or decorate it.
- Braze*.—To join two pieces of metal by fusing a layer of brass or brass alloy between the adjoining surfaces.
- Brush flame*.—Torch flame shaped like a brush, which distributes heat widely.
- Bump (metal)*.—To hammer damaged sheet metal back to approximately its original shape, using a bumping hammer and dolly against the ridges and channels.
- Bur (burr)*.—A rough or sharp edge left on metal by a cutting tool; also, an L-shaped edge on a sheet of metal.
- Calk*.—To tighten or close a joint; calking tool is also used to open a joint.
- Chord*.—A straight line drawn between two points on a curve.
- Concave*.—Curved inward.
- Convex*.—Curved outward.
- Corrosion*.—The slow wearing away of metals by chemical attack, of which rust is a common form.
- Corrugated*.—Uniformly wrinkled or furrowed; formed into alternate ridges and channels.
- Crown*.—An arched surface.
- Dezincification*.—Removal of zinc from brass or alloys by electrolysis, caused by strong alkalies and certain salts.
- Dies*.—A pair of cutting or shaping tools which, when pressed or stuck against each other, shape an object or surface between them.
- Ding*.—To strike with a light hammer.
- Electrolysis*.—Transfer of metal by an electric current in a liquid.
- Filler*.—Metal rod melted in welding to fill spaces in the piece or pieces being welded.
- Flux*.—A substance used to remove oxide from a metal surface to be soldered, brazed, or welded, and thus promote their union.
- Fuse*.—To liquefy metal by heat.
- Gage (gauge)*.—An instrument for measuring dimensions, pressure, and volume; also, the thickness of sheet metal, referred to by number.
- Jig*.—An appliance used in shops for accurately guiding and locating tools while producing standardized shapes or forms.
- Muriatic acid*.—Hydrochloric acid, used in weak concentration to clean metal.

Needle flame.—Torch flame shaped like a needle, which delivers a heavy concentration of heat.

Oxidize.—To combine with oxygen; rust and burning are common forms of oxidation.

Oxyacetylene.—Consisting of or using a mixture of oxygen and acetylene.

Plastic.—Capable of being molded in a solid form by outside force and retaining that form after the force is removed.

Sal ammoniac.—Ammonium chloride, used to clean metals by etching.

Seam.—A sheet metal joint, usually riveted, soldered, or welded.

In a lock seam, the sheets have turned edges, which are hooked together to provide strength. In a lap seam, the sheets, without any special edging, are simply overlapped and riveted, soldered, or welded.

Standard, machine.—The upright on which a machine is supported on a bench.

Strain (in metal).—Internal forces that change the shape of the metal, if not resisted by other internal forces.

Stress.—The external forces exerted on a body or the internal forces resisting them.

Swage.—To groove sheet metal by a machine or hand tool.

Sweat (or sweat solder).—To solder by tinning the metal surfaces and heating them while they are pressed into contact.

Tack weld.—Temporary welding, usually in spots, to hold the pieces together while the permanent weld is being made.

Telescoping.—Adjustable in length by sliding one section of a tube within another, as in a telescope.

Terne plate.—Thin coating of lead on steel or iron to prevent corrosion.

Thrust.—A stress or strain tending to push any thing out of alignment, or the change of shape caused by it.

V-channel.—Major indentation in a damaged metal panel, caused by an impact.

Welding.—Joining of iron or steel by heating the contacting surfaces until the metal fuses together. The heat is produced in *arc* welding by an electric arc struck between a welding tool and the metal to be joined; in *flash* welding, by an arc struck between the pieces of metal to be joined; and in *resistance* welding, by electric current flowing through the surfaces to be welded, which are pressed together.

SECTION II

SHEET METAL WORK

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6. General.—Since sheet metal comes from the mills in standard lengths, widths, and thicknesses, it must be cut and shaped in the shop. This requires sheet metal working machines such as shears, folding machines, brakes, forming machines, and punch presses, as well as many hand tools such as tinner's shears, files, mallets, and chisels. After the metal has been cut and shaped, it is sometimes necessary to join the pieces by soldering, welding, or brazing.

7. Sheet metal working machinery.—*a. Shears.*—(1) These are required when large sheets of steel, brass, copper, or aluminum must be cut before an article is formed and shaped. Many kinds of sheet-metal shears are manufactured, but squaring shears, though used only for squaring and trimming, are most important.

(2) Foot-operated squaring shears are used for cutting light, small stock; and foot-controlled power operated shears (fig. 1) for cutting heavy, large stock. They are alike in their operating principles except that on the foot-operated squaring shears the upper cutting blade is lowered by foot pressure on a treadle; whereas, the cutting blade in the power squaring shears is driven by a belt from a line shaft, or geared directly, as in figure 1. In both of them, the material to be cut is secured by hold-downs. On power squaring shears the stroke of the upper cutting blade is controlled by a positive automatic clutch, tripped by stepping lightly on a treadle. Unless the treadle is kept down, the cutting blade stops at its highest point after making one cut.

(3) A simple manually operated slitting shear (fig. 2) is useful in cutting straight strips from light-gage sheet metal. It is small enough to be mounted on a bench at a convenient height. To operate it, clamp the sheet metal on the supporting table with the hold-down plate and pull the hand lever forward for cutting. The cutting blades may be removed for sharpening.

(4) Rotary shears come in a variety of sizes and capacities, but in principle they are all the same. The shear shown in figure 3 may be used to cut sheet metal into curved strips. When the sheet metal is held securely by the two small clamping disks and the hand crank turned, the rotary cutters revolve, cutting a circular piece. Moving the sliding circle arm to the left increases the distance between the clamping disks and the rotary cutters and thereby increases the diameter of the piece cut. It is necessary to increase the pressure be-

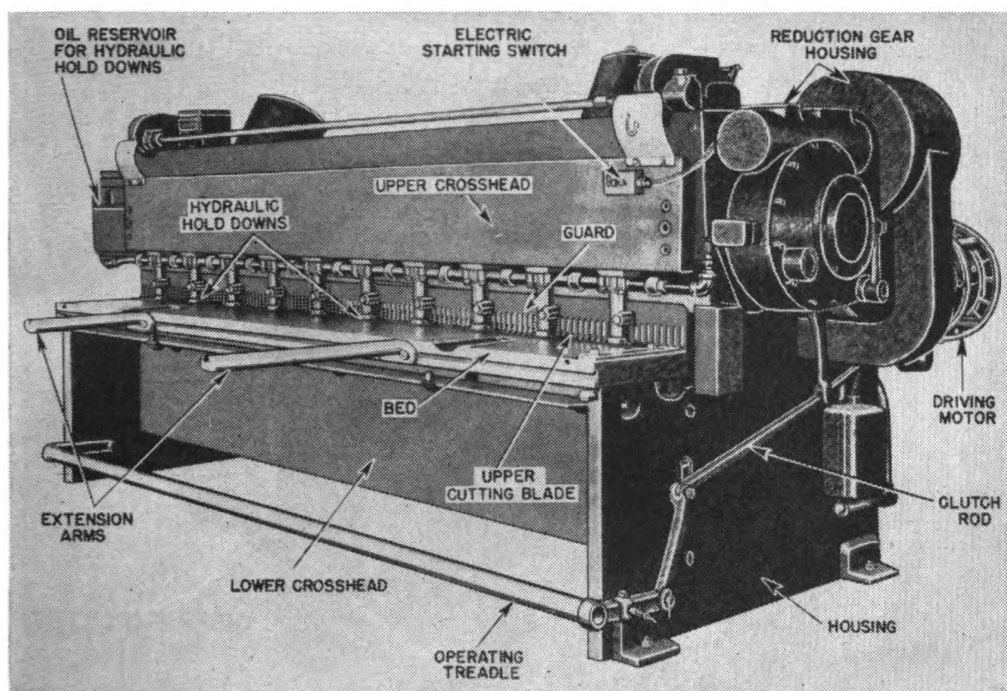


FIGURE 1.—Foot-controlled power squaring shears.

tween the cutters as they rotate by turning the cutter pressure lever. When cutting very narrow strips, the rotary cutters have a tendency to curl the metal and twist it out of shape.

(5) The unishear (fig. 4) is used to cut irregular shapes from odd designs scribed on sheet metal work. It operates on the same principle as common household scissors in that the upper jaw is held stationary while a motor-driven eccentric moves the lower jaw up and down. Any shape desired may be cut by merely changing the angle at which the sheet metal is fed into the cutting jaw.

b. Folding machines.—(1) Folding machines are used to form edges (fig. 5) in sheets of metal, which will have wire inserted or will be used simply as flanges. Manually operated folding machines are usually more desirable than power-driven models for light, rapid work.

(2) The bar folding machine (fig. 6) is a popular type for general use. A wedge raises the wing to fold a closed single or double edge, or lowers it to form an open lock which will receive a wire (wire

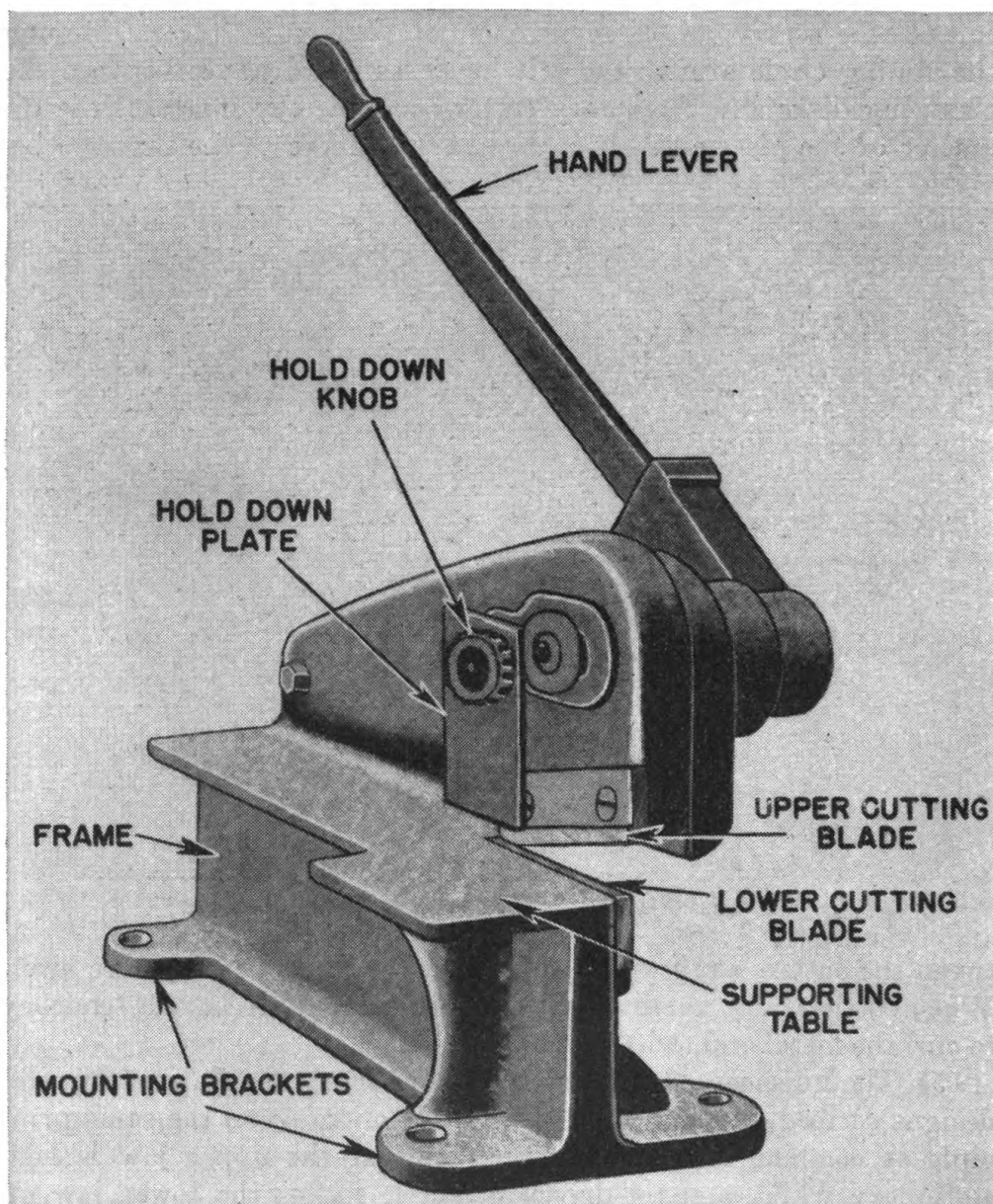


FIGURE 2.—Simple manual slitting machine.

wedge). To manipulate the wedge-adjusting lever, hold the folding bar at a little more than a right angle to the edge of the folding blade. After securing the correct adjustment, fasten the wedge-locking lever. Two angular stops, when properly set, will limit the move-

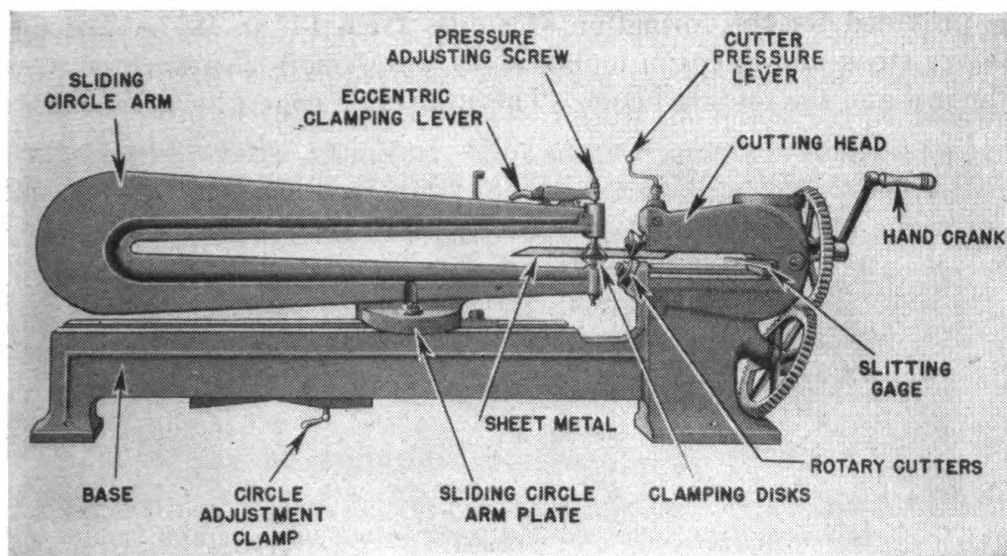


FIGURE 3.—Rotary shear.

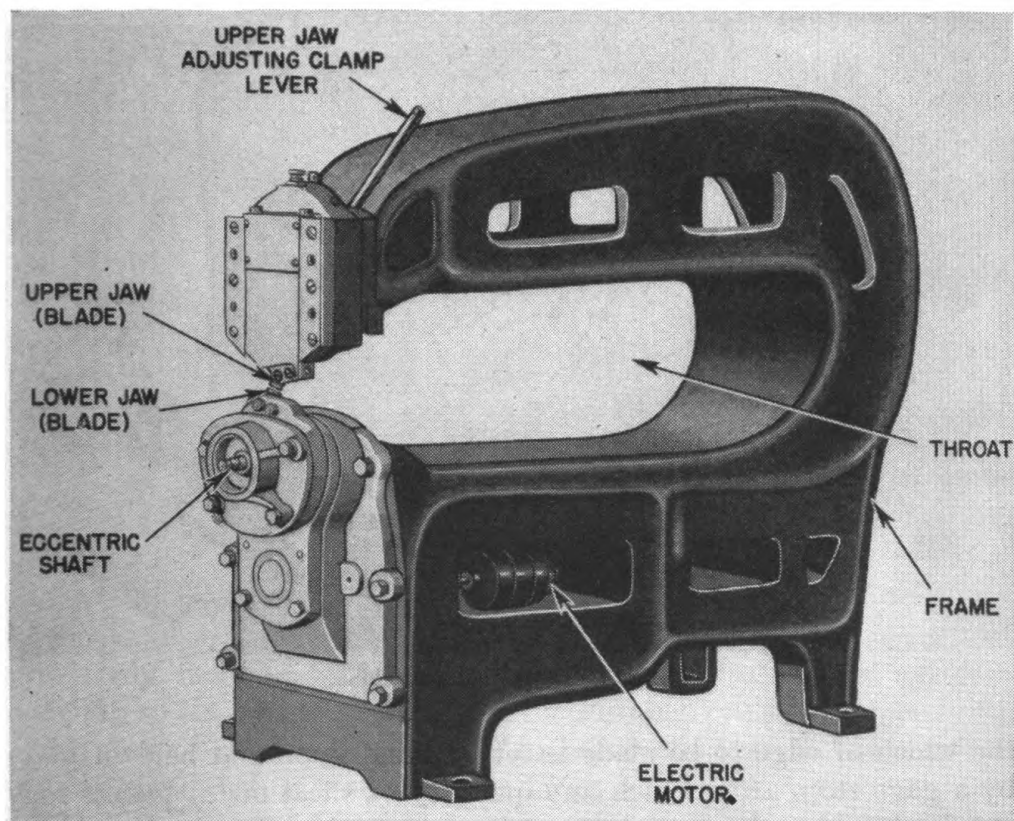
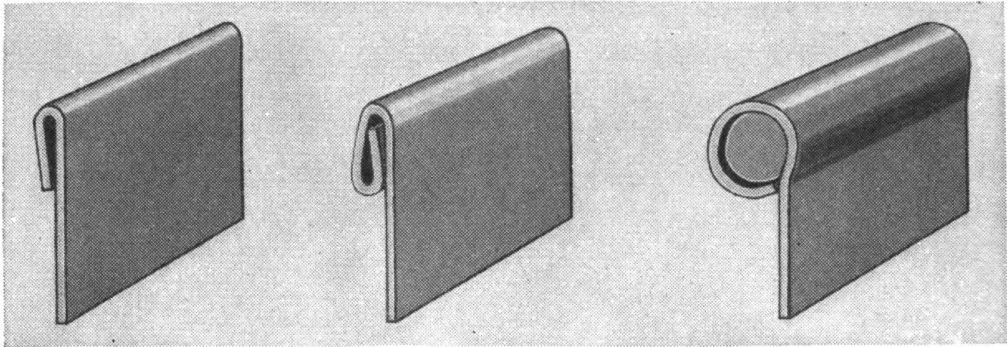


FIGURE 4.—Unishear.

ment of the folding bar for a 60° or 90° angle. An adjustable stop is provided for the formation of angles from 10° to 120° . To edge heavy stock and to form double edges, allow more clearance between the jaw and the folding blade. The adjustable gage which determines



① Single.

② Double.

③ Wire.

FIGURE 5.—Common edges used in sheet metal work.

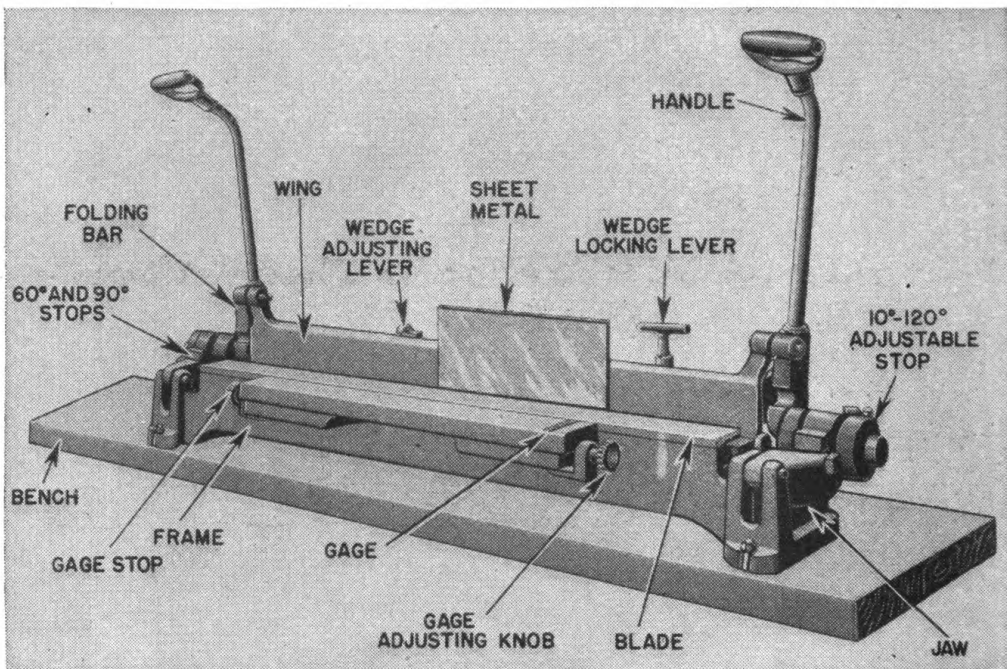


FIGURE 6.—Bar folding machine.

the width of edge to be made is set by hand knob and held in place by a gage stop, after which any quantity of sheet metal blanks may be edged uniformly.

(3) The single edge (fig. 5) is used in constructing seams and hemming the edges of sheet metal. In forming this edge with a fold-

ing machine, set the gage and insert the metal between the blade and the wing, holding it firmly against the gage with the left hand. Grasp the handle with the right hand and bring the folding bar over until it rests on top of the machine. Now return the handle to its former position and remove the metal. This single edge can be made stronger by folding it back on itself, making a double edge.

(4) Wire edges also increase the strength of articles made from sheet metal. To form an open or round edge in which a wire may be enclosed, set the gage on the folder at a width equal to two and one-half times the diameter of the wire, and adjust the wedge to the diameter of the wire. When the edge-locking lever is firmly fastened, turn the edge in the usual manner.

(5) In computing the amount of sheet metal necessary to make an edged sheet of a certain width, be sure to allow enough metal to include the entire edge. The metal required to form a single edge is triple the width of the edge. When heavier material is used and accuracy is required, the actual amount of material taken up by bends must be added.

c. Brakes.—Brakes differ widely from folding machines in construction and operation, although both are regularly used for folding. The folding machine can form a lock seam or edge only as wide as the depth of the wing will permit; whereas, the brake, which allows the sheet metal to pass through the bending leaves from front to back without obstruction, forms locks and edges in a wide range of sizes and unusual lengths. Figure 7 illustrates a typical brake, in which the sheet to be edged is securely clamped on a bed until the bend has been made.

d. Forming machines or rolls.—(1) These are found in almost every sheet metal shop and are very useful for forming sheet metal into cylinders of various diameters. Although the mechanism has many variations, forming machines are alike in principle, consisting mainly of a left and right frame with three solid steel rolls connected by gears, which do the forming. The two front rolls grip the sheet metal and force it against the rear roll, which bends it around the upper front roll to form a cylinder that may be closed by a lock previously made in a folding machine. The size of the cylinder depends on the nearness of the rear or forming roll to the upper roll. The pressure of the gripping rolls against the rear forming roll is usually regulated by a small screw lever.

(2) The slip roll forming machine (fig. 8) has open-type frames with clamps to hold the rolls in proper position. Opening the clamps allows the operator to lift the rolls and very easily slip off the sheet

metal cylinder formed. With forming machines having solid frames, the cylinder must be slipped over the front upper roll, and thus is likely to be thrown out of shape. This is impossible where a slip roll forming machine is used.

e. Bench machines (figs. 9 and 10).—(1) Bench machines are used to operate pairs of interchangeable rolls which bead, swage, or bur sheet metal. To use these machines place the sheet metal between the rolls, pressing its edge against the gage, and adjust the gage to locate the bead or bur properly. The upper roll is depressed by turning the pressure-adjusting screw. Turn the hand crank with the right hand and guide the work with the left hand, as the metal moves between the revolving rolls.

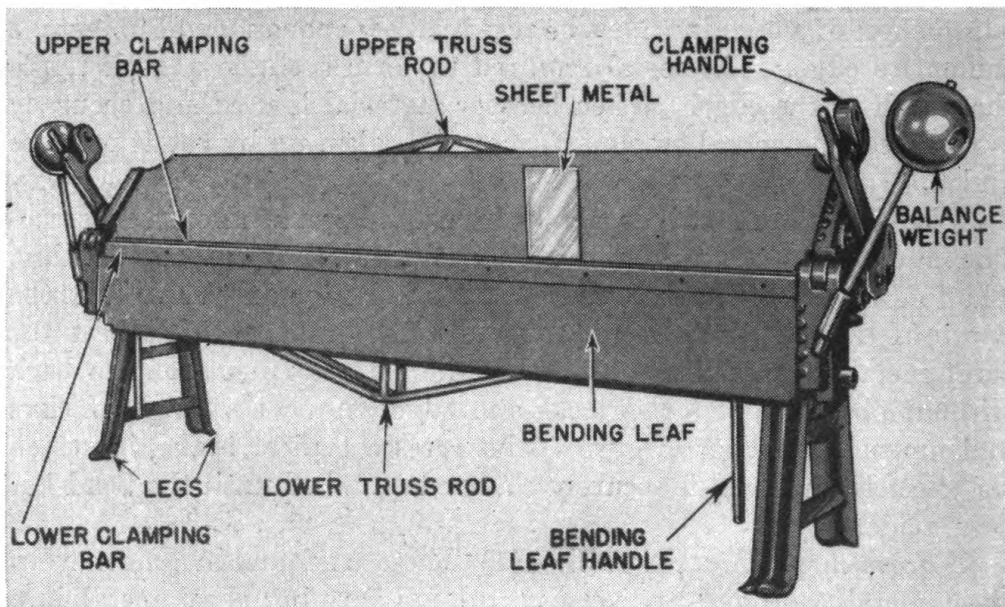


FIGURE 7.—Cornice brake.

(2) With beading or swaging rolls (fig. 9), the machine is used for making depressions in sheet metal and for stiffening and ornamenting automotive bodies and fenders. Select rolls of suitable size in single bead, double bead, or triple bead, whichever will show most attractively on the work.

(3) With burring rolls (fig. 10), the machine is used to crease or flange light metal work. Heavier burring machines of different construction from the bench models are available for putting narrow or wide flanges on very heavy gage material. It is more difficult to operate the bench machine with burring rolls than with beading rolls. A knack is required for holding the work in the right position,

and a proper and uniform speed is necessary to produce a crease or flange without buckling. To turn a bur without crimping or warping requires both instruction and practice.

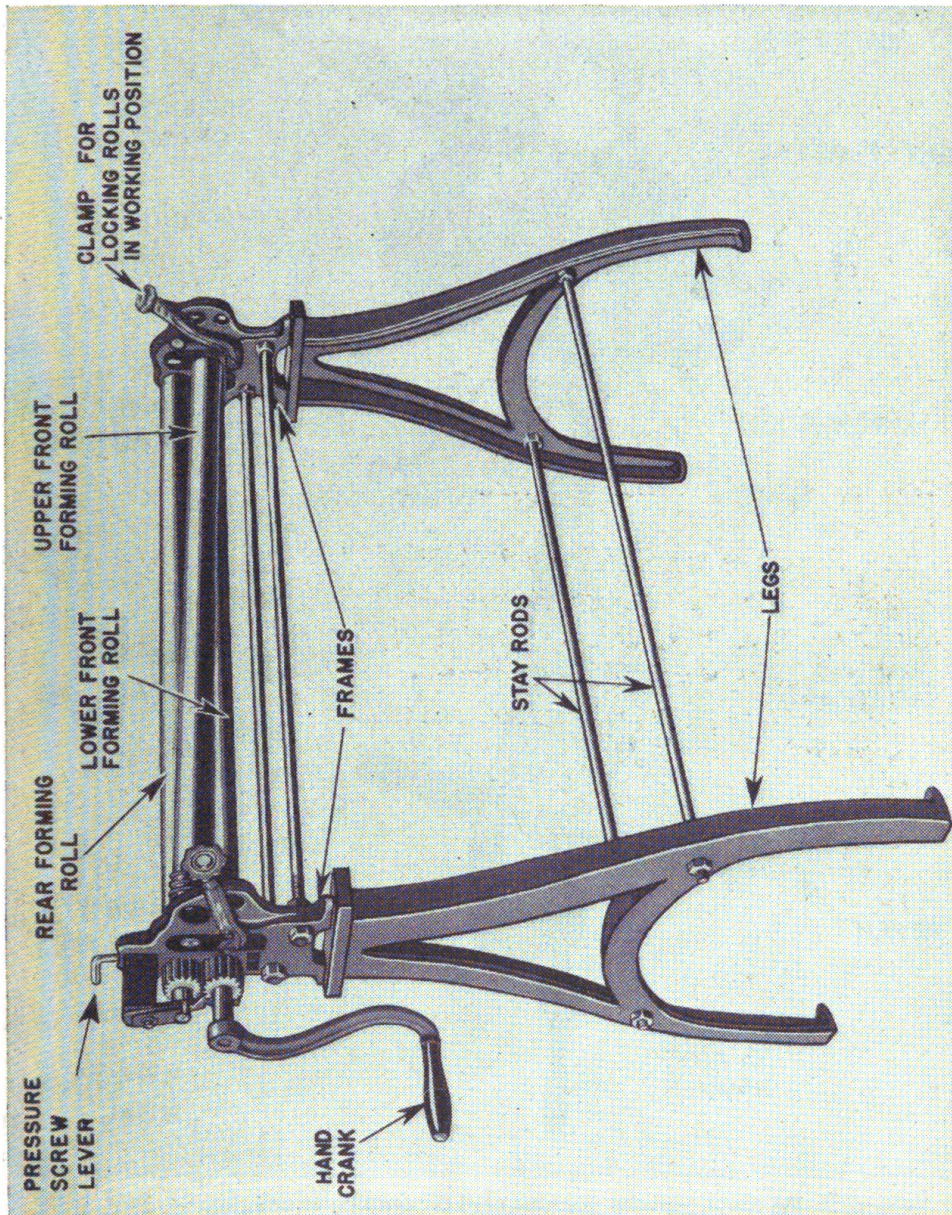


FIGURE 8.—Slip roll forming machine.

f. Mechanical power press (fig. 11).—This press is used extensively in sheet metal work for punching holes of various sizes and shapes and for blanking, trimming, and simple drawing. It has but one moving plunger or ram, to which the punch is attached. Most standard presses of the smaller sizes are made with an opening in the

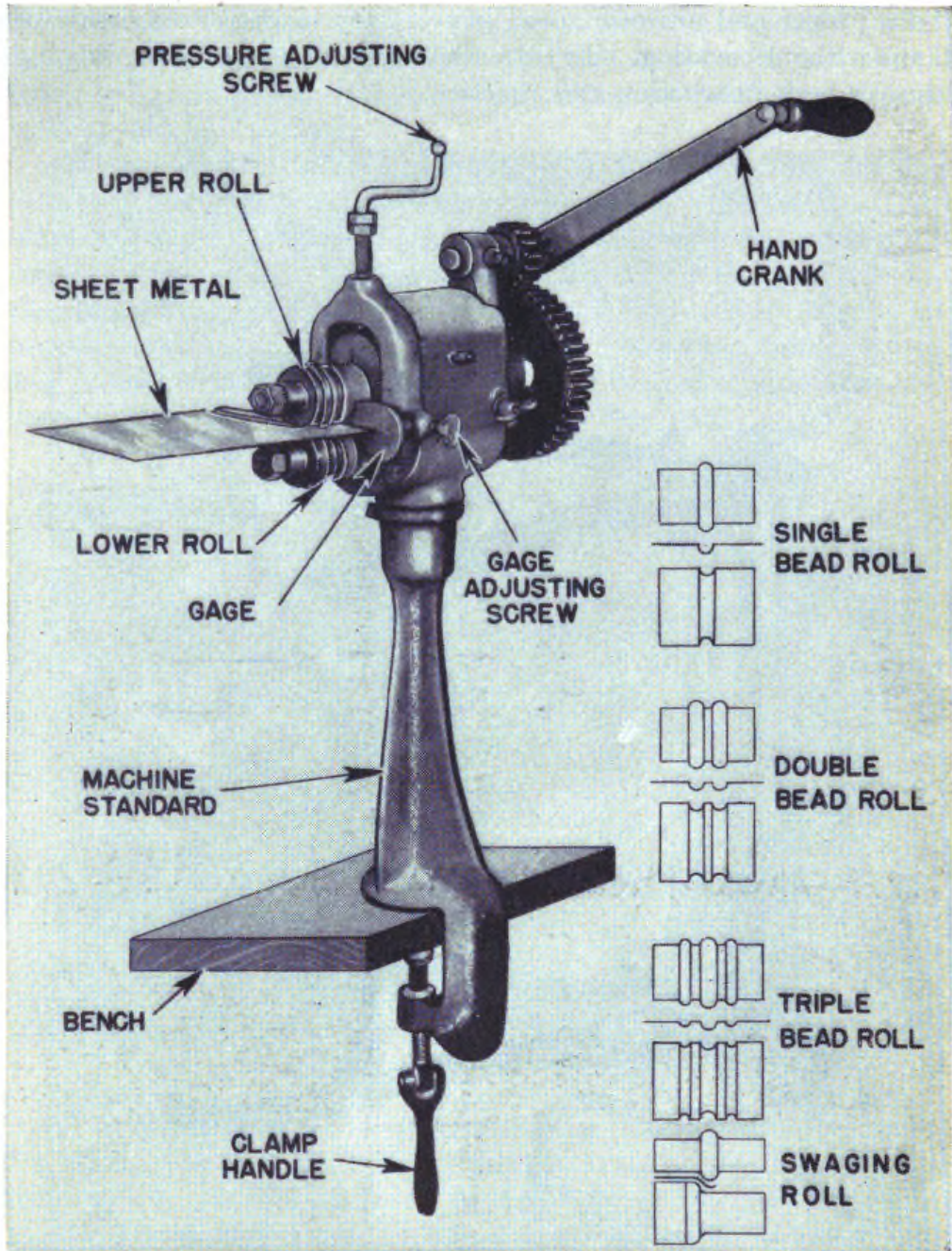


FIGURE 9.—Bench machine used for beading or swaging.

lower end of the ram to hold the shank of the punch block. The die, which has a cavity to receive the punch, is mounted on the bolster frame, which in turn is bolted to the press bed. The punch and die are held in alinement by the ram in its ways and by the rigidity of the press frame. The stripper plate fixed to the ways of the ram

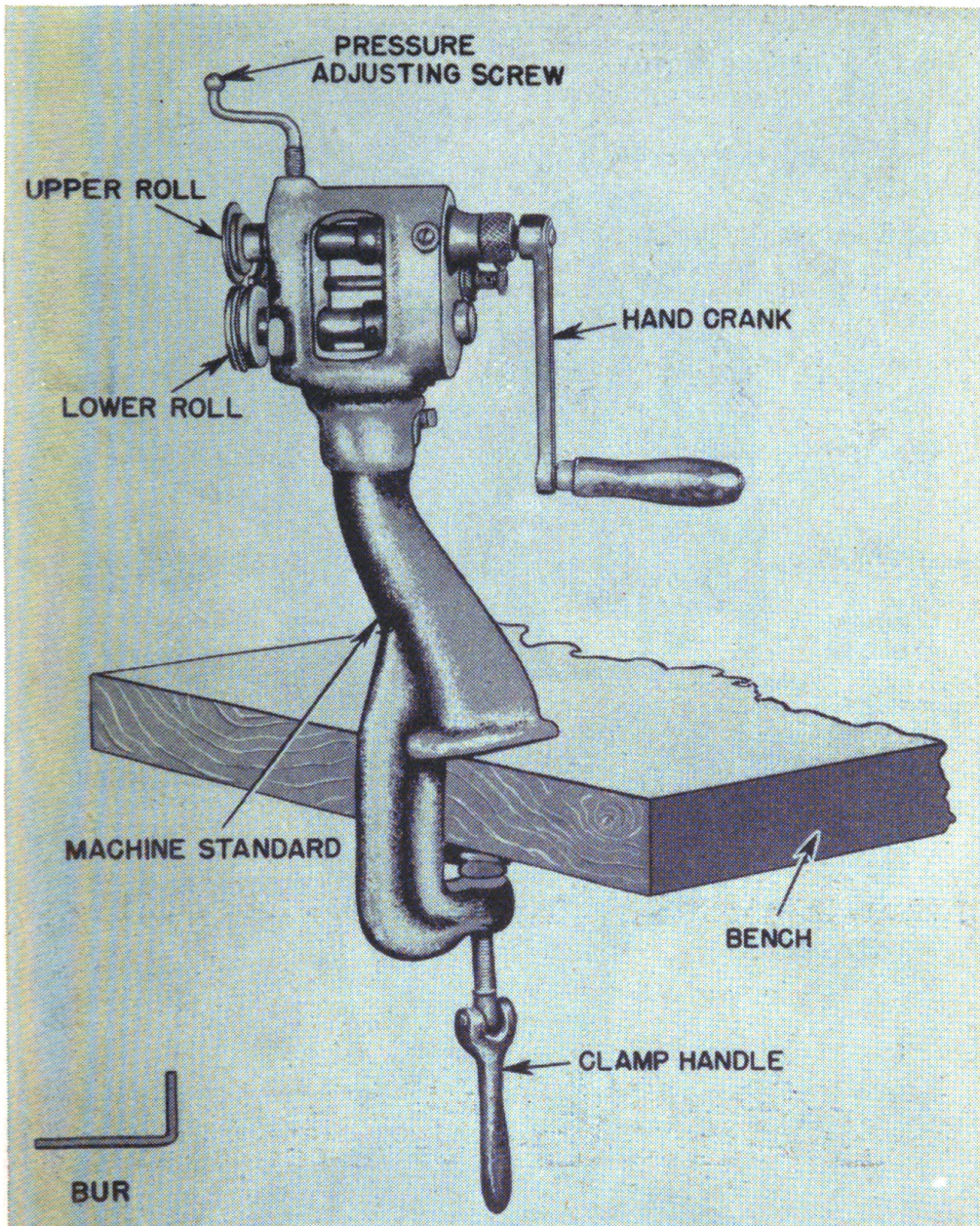


FIGURE 10.—Bench machine used for burring edges.

prevents the sheet metal from sticking to the punch as the ram is withdrawn. The press is operated by the trip pedal.

8. Sheet metal hand tools.—*a.* Shaping sheet metal by hand is principally done by bending it over anvils of peculiar forms known as stakes. These fit into tapered holes cut in the work bench or a bench plate. Some commonly used bench stakes are shown in figure 12.

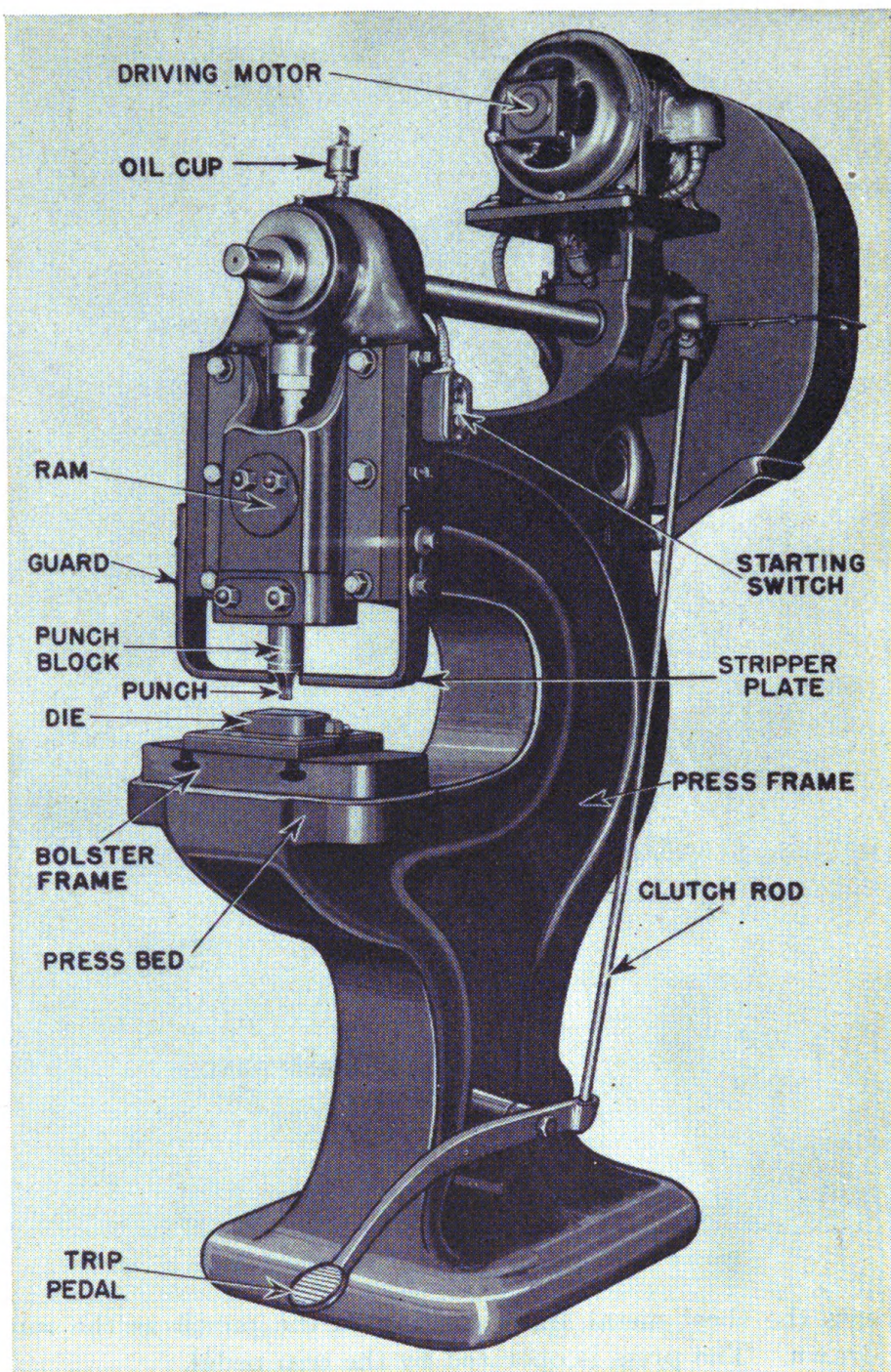


FIGURE 11.—Power-driven punch press.

6. Hand snips or shears are made with straight blades for straight cutting and curved blades for circular cutting. They are made for both right- and left-hand operators.

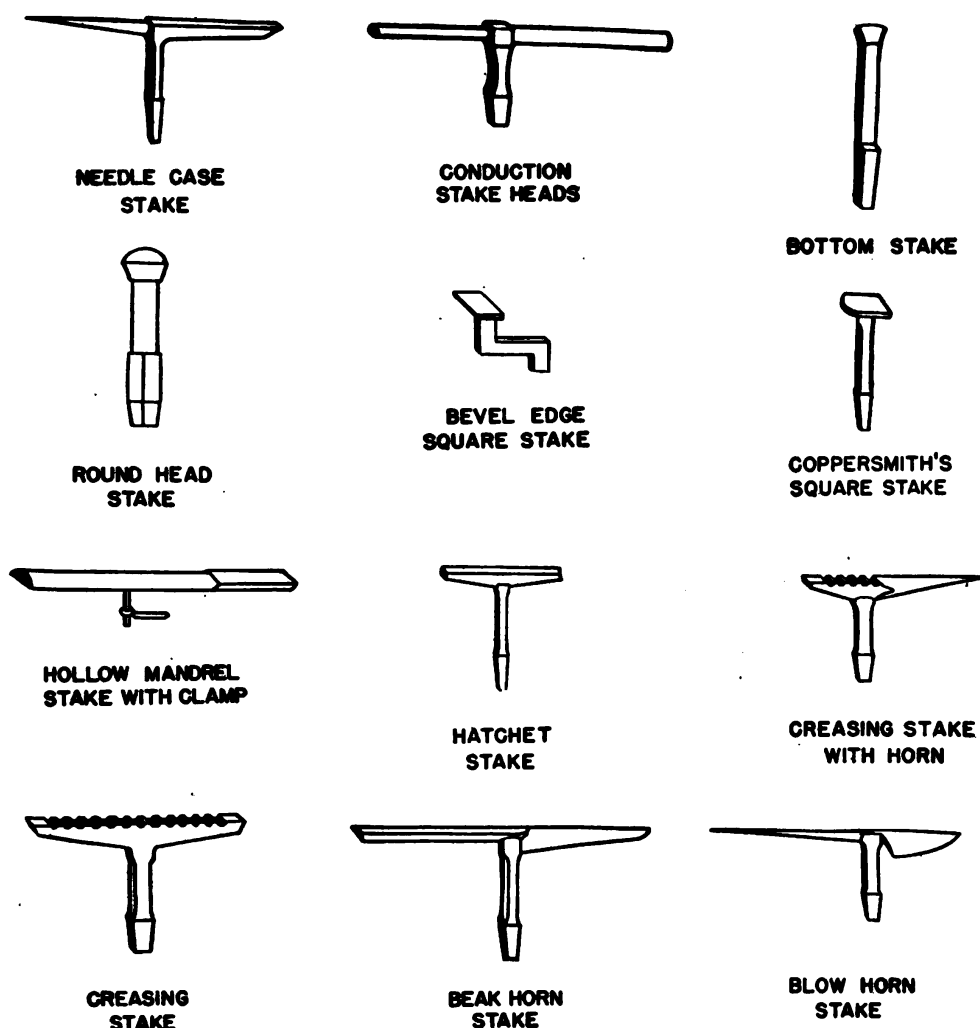


FIGURE 12.—Bench stakes.

c. Other tools often used in the sheet metal shop are—

Raising hammers, for raising and stretching metals.

Soldering coppers, for soldering.

Rules, including squares and gages.

Rivet sets, to force metal down on rivets.

Punches, prick, drive-out, center, and taper.

Scriber, for lay-out work.

Pliers, side-cutting, flat nose, long nose, etc.

Dividers, large and small.

Hammers, tinnerns, ball peen, copper, and riveting.

Torches, gas, gasoline, or charcoal.

Mallets, wood and rawhide.

Files, solder and 12-inch bastard.

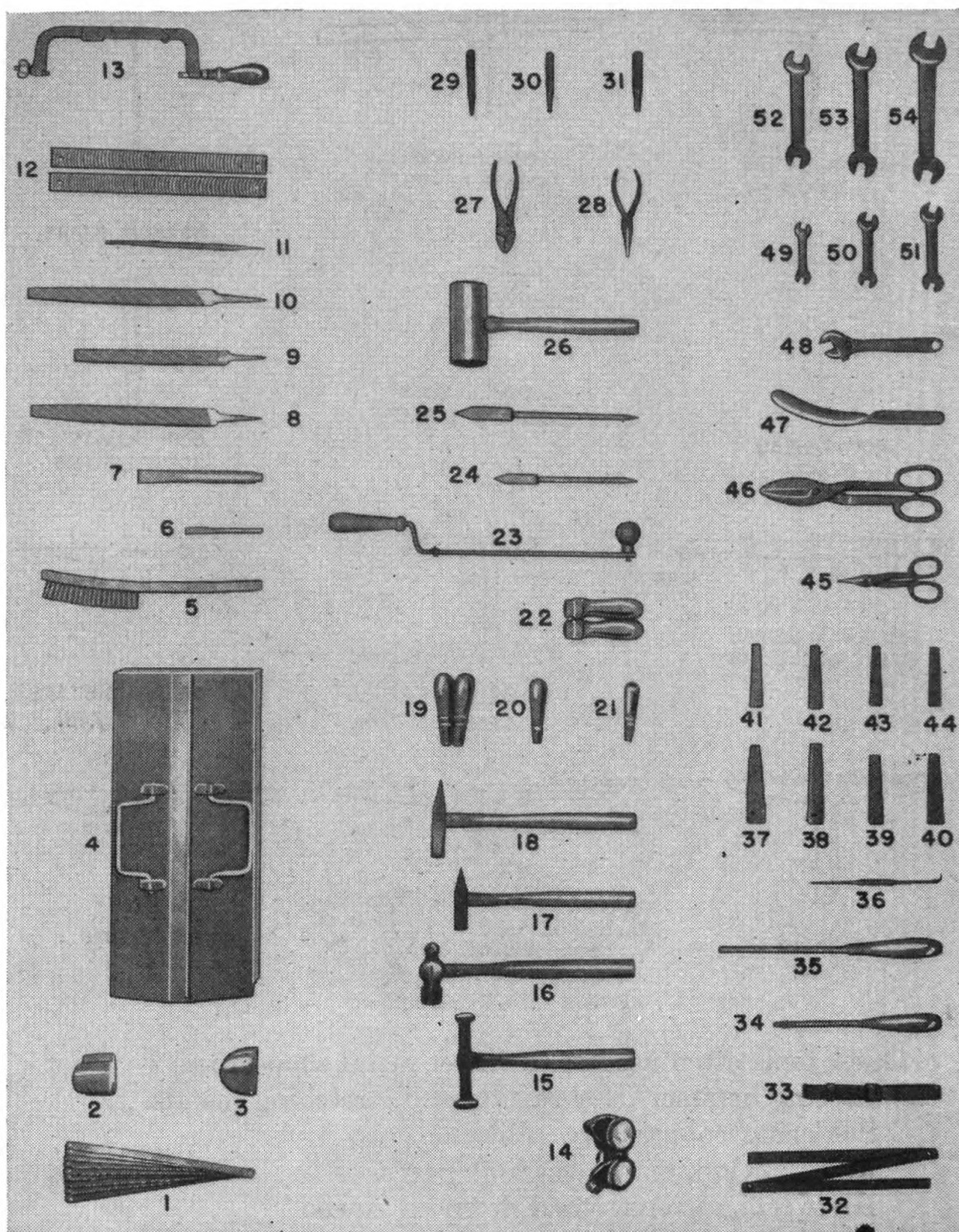


FIGURE 13.—Sheet metal and radiator mechanic's tool set.

Screw drivers, large and small.

Adjustable wrenches, 6-inch or 8-inch.

Cold chisels, $\frac{7}{8}$ -inch and $\frac{1}{2}$ -inch diameter.

Groover, $\frac{1}{4}$ -inch and $\frac{3}{8}$ -inch.

d. Figure 13 shows a complete set of tools for field service authorized for sheet metal and radiator mechanics as part of third

echelon equipment unit set No. 1 for light maintenance companies of the Quartermaster Corps. A complete set includes the following tools:

Type of tool	Item No.	Description
Blades, saw-----	1	Hack, type A, all hard, length 12 inches, width $\frac{1}{2}$ inch or $\frac{3}{16}$ inch, points per inch 24.
Blocks, dolly-----	2	General purpose type III, 70 percent to 85 percent carbon steel drop-forged.
	3	Heel type IV, 70 percent to 85 percent carbon steel, drop-forged.
Box, tool-----	4	Loose tray, O. D., length 21 inches, width $8\frac{1}{2}$ inches, depth $7\frac{7}{16}$ inches.
Brushes-----	5	Cleaning, steel wire, rectangular-handled, width $1\frac{1}{8}$ inches.
Chisels-----		Machinists', hand, cold, with polished faces and heads:
	6	Width of cut $\frac{3}{8}$ inch, length $5\frac{1}{2}$ inches.
	7	Width of cut $\frac{1}{4}$ inch, length 8 inches.
Files, American standard-----	8	Flat bastard, 12 inches (point-to-shoulder).
	9	Half-round bastard, 10 inches (point-to-shoulder).
	10	Mill bastard, 12 inches (point-to-shoulder).
Files, Swiss-----	11	Round bastard, 8 inches (point-to-shoulder).
	12	Pattern, Vixen, flexible, flat without tang, length 14 inches.
Frames-----	13	Hack saw, adjustable, straight handle, capacity 8 inches to 12 inches.
Goggles-----	14	Welders' eyecup, with lenses, shade No. 5.
Hammers-----	15	Dinging, 13 ounces with handle.
	16	Machinists', ball peen, 16 ounces.
	17	Riveting, 9 ounces.
	18	Riveting, 18 ounces.
Handles-----	19	Large file-and-tool, $1\frac{1}{2}$ -inch handle diameter.
	20	Medium file-and-tool, $1\frac{1}{4}$ -inch handle diameter.
	21	Small file-and-tool, 1-inch handle diameter.
	22	Soldering-copper.
Holdes-----	23	Flexible, for 14-inch file.
Irons (coppers, soldering)-----		Nonelectric, pyramid point.
	24	1 pound per pair.
	25	2 pounds per pair.
Locks-----		Pad, general purpose, pin tumbler mechanism, plain, size $1\frac{1}{2}$ inches, bronze case and steel shackle, type 1B.
Mallets-----	26	Tinners', diameter $2\frac{1}{2}$ inches, length $5\frac{1}{2}$ inches.
	27	Combination, slip joint (wire-cutting type), length (over all) 6 inches.
Pliers-----	28	Long, flat, wide nose (noncutting style), length (over all) 6 inches.

Type of tool	Item No.	Description
Punches, center-----	29	Type 11, octagon or round (knurled), diameter of stock, $\frac{3}{8}$ inch, length $4\frac{1}{2}$ inches.
Punches, drive-pin----	30	Solid taper, with polished faces and heads: $\frac{1}{4}$ -inch diameter.
	31	
Rules-----	32	Blacksmiths', steel, folding, length 36 inches, 3 folds.
Scrapers-----	33	Carbon 10-spring-steel wire with sliding ferrule. Common, heavy duty, integral handle.
Screw drivers-----	34	6-inch blade.
	35	10-inch blade.
Scribers-----	36	Machinists', length 9 inches.
		Rivet, hand, coppersmiths' and tinsmiths':
		Size Length (inches)
	37	00 $5\frac{1}{2}$
	38	0 $5\frac{1}{2}$
Sets and headers-----	39	1 5
	40	2 5
	41	3 $4\frac{1}{2}$
	42	4 $4\frac{1}{2}$
	43	5 $4\frac{1}{2}$
	44	6 $4\frac{1}{2}$
	45	Hand, combination, length of cut $1\frac{1}{4}$ inches, length (over all) 7 inches.
	46	Hand (snips), straight-cut, length of cut 3 inches, length (over all) $12\frac{1}{4}$ inches.
Spoons-----	47	Body, wide.
Wrenches, adjustable--	48	Crescent type, jaw opening (minimum), $\frac{15}{16}$ inch, length (over all) 8 inches.
		15° angle, double-head, open end:
		Dimensions of opening (inch)
	49	$\frac{3}{8}$ and $\frac{7}{16}$.
Wrenches, engineers'--	50	$\frac{1}{2}$ and $\frac{19}{32}$.
	51	$\frac{9}{16}$ and $1\frac{1}{16}$.
	52	$\frac{5}{8}$ and $1\frac{5}{16}$.
	53	$\frac{3}{4}$ and $\frac{7}{8}$.
	54	$1\frac{1}{16}$ and 1.

9. Soldering.—*a. General.*—(1) Soldering is the use of fusible alloys for joining metals. The kind of fusible alloy used, hard solder or soft solder, depends on the metal to be joined, but it should always be more fusible than the metal.

(2) Hard soldering, called brazing, makes a stronger joint and withstands higher temperatures than soft soldering. Soft soldering is used when the articles to be joined must be made air- or water-

tight. It is much the simpler operation, and therefore should be used where possible in place of brazing.

(3) The beginner usually experiences trouble with solder not "sticking," or when it does "stick" it forms lumps and makes an unsightly job. Soldering, however, is not a difficult process. It merely requires a certain knack which can be acquired only by practice.

(4) Sheet metal can be soldered with either a soldering copper (iron) or a soldering torch.

NOTE.—A torch cannot be used on a fuel tank (see par. 14). Although these tools are quite different, most jobs may be done with either.

b. Preparing surface.—(1) Cleaning the metal surface is the first step in successful soldering. The object is to remove the film of oxide that forms on the surface of common metals exposed to air. This film prevents the solder from coming into intimate contact with the metal, and makes fusing impossible. Remove the film with either a scraper or a wire brush, or with weak acid (usually muriatic) for a heavily oxidized surface. Be careful not to touch the cleaned surfaces with the fingers, as they will leave a deposit of grease that interferes with the ability of the solder to stick. To limit the formation of more oxide, the cleaned metal surface should be protected from the atmosphere as quickly as possible with flux.

(2) Liquid flux is applied with a small brush, acid swab, or squirt can. When cut acid is used as a flux, the water in it turns to steam under soldering heat and is lost. This either drives the flux or makes a heavy and sirupy mass, so that additional water is required to maintain full effectiveness.

(3) A good solderer habitually applies more water or flux to the metal while changing or reheating the soldering tool. He knows that the heat from the tool has dried the flux at the point where the tool was removed, and he knows solder will not stick unless the flux is renewed. *Keep the flux diluted with water at all times.*

10. Soldering with copper.—*a. General.*—(1) The soldering iron or copper is a copper bar with a handle of steel and wood. Selecting the weight of a copper is very important. A heavy copper will hold its heat longer than a light one, but a medium or lightweight copper is easier to manipulate. Beginners should start by using one of medium weight. The lightweight copper is used by radiator repairmen, who require only a little solder at a time and, therefore, prefer an easily manipulated tool to one that retains its heat a long time.

(2) An electric soldering copper is very convenient if a 110-volt source of a-c or d-c current is available to operate it. Because it

heats quickly and remains hot as long as the current is on, it works faster than ordinary coppers, which occasionally must be reheated. If an electric copper becomes too hot, the current can be turned off for a few minutes.

b. Preparing copper for use.—(1) This involves heating, hammering, annealing, and filing the point; and finally reheating to a proper soldering temperature and tinning. Some of these steps are not required every time the copper is used, but it must always have a well formed, well cleaned, and well tinned point.

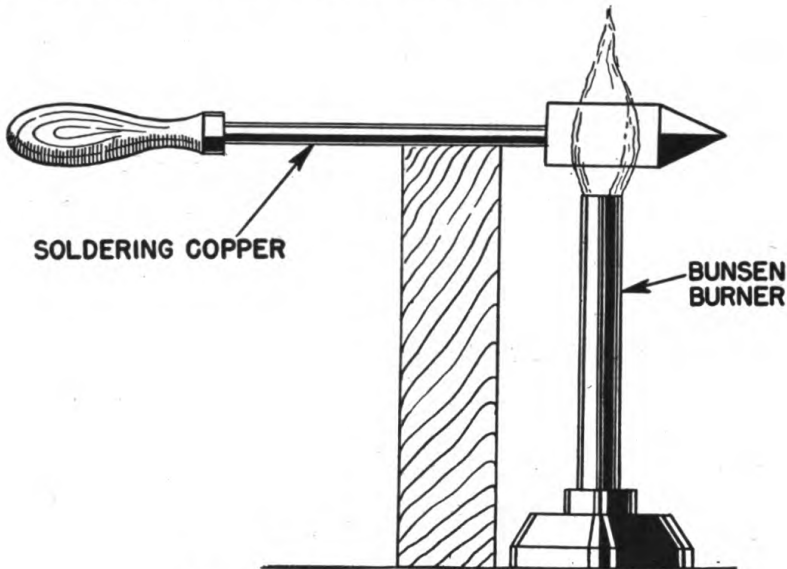


FIGURE 14.—Heating a soldering copper.

(2) Coppers are heated by several different methods. If a hot gas flame, such as a bunsen burner, is used, the soldering copper should be held as shown in figure 14, with the point outside the flame.

(3) Because of the high heat conductivity of the copper, the point will be heated, without burning, to practically the same temperature as the back. When a gas burner is not available, a gasoline torch or a portable fire pot with a charcoal fire can be used. Take care not to let the copper touch the charcoal as the surface will become dirty.

(4) If the copper does not have a good point, heat it to a dull red and hammer a point tapering back about one-fourth the length of the copper to form the shape shown in figure 15. Then anneal it by plunging it red hot into cold water. This not only softens the copper for filing, but enables it to take tinning well (see *c* below), and makes it give off heat better. When the copper is being redressed, all the old solder should be burned or filed off before hammering, or the copper will become hard.

(5) Next file all rough spots from the pointed end of the copper, finishing with a fine file to a flat, smooth surface for the tinning. The better the copper is polished, the longer the tinning will last. Tinning puts a smooth, clean film of solder on the surface of the copper which is essential for a good soldering job.

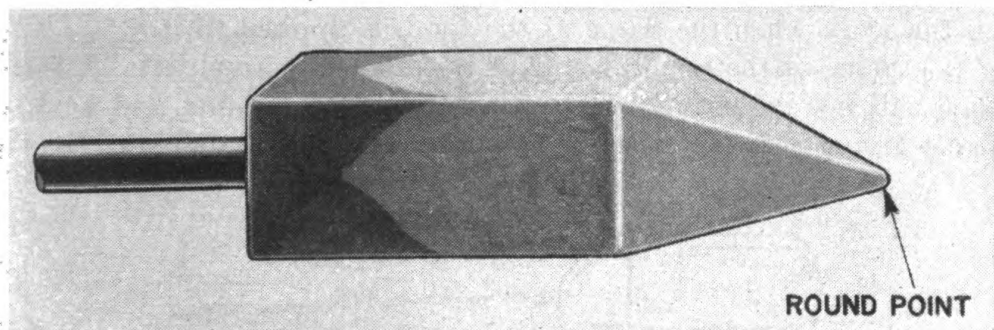


FIGURE 15.—Soldering-tool point.

c. Tinning copper.—(1) To tin the copper, heat it to a point that will just melt solder readily; too hot a copper will not take tinning well or hold it long. Rub each face on a block of sal ammoniac and apply a bar of solder to the copper at the same time, allowing a bright film of solder to cover the point thoroughly.

(2) Clean the tinned point each time it is removed from the heater, for it easily becomes coated with the oxidation of solder and the residue from flux. When pits form on the copper just back of the tinned surface, heat it and wipe them off on a clean, wet rag.

d. Applying solder.—(1) This is done by resting the point of the heated copper on the surface to be soldered and allowing the bar of solder to melt in contact with the copper and flow onto the surface. To solder successfully, the copper must be neither too hot nor too cold. One condition is just as bad as the other. If the copper is chilled, the solder will not run freely, and the small amount that does reach the inadequately heated surface of the work will not stick. If the soldering copper is too hot, the solder will form little globules which run off the metal surface before they can cool.

(2) As a rule, the copper should be just hot enough to melt the solder after they have been in contact for a few seconds. If the solder is melted instantaneously, the copper is too hot; if it is melted slowly, the copper is too cold.

(3) In a good soldering job, the solder is spread or “flowed” evenly over the metallic surfaces and adheres until it is removed by the further application of heat. If it hardens in lumps, they can generally be picked off with the fingers.

11. **Soldering with torch.**—*a. General.*—(1) The rapidity with which soldering can be done with a torch gives it an advantage over the copper as a soldering tool. The torch is valuable for melting when dismantling soldered parts. The method of applying solder with a torch does not differ greatly from soldering with a copper. With a torch, however, the bar of solder is melted and flowed directly on the work when the flame of the torch is applied to it.

(2) Some of the requirements of a satisfactory torch are: A flame that will not be extinguished by the fumes of the flux and acid; a flame giving sufficient heat to accomplish soldering quickly, yet *not*

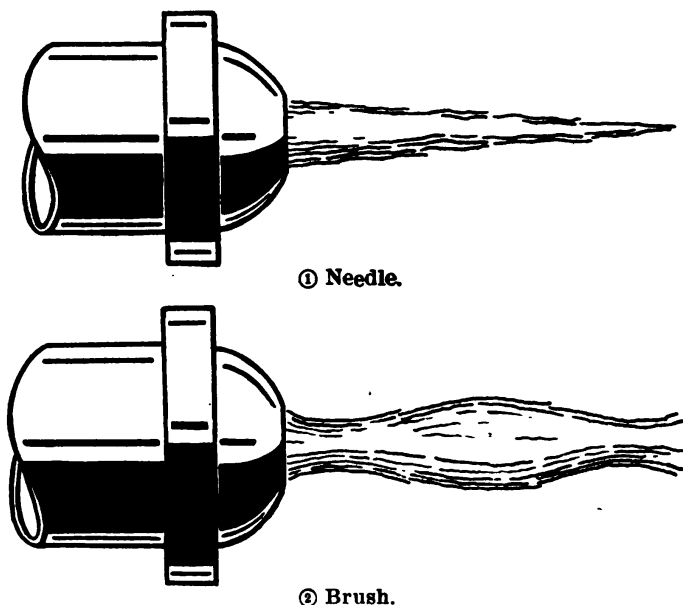


FIGURE 16.—Torch flames, artificial gas.

hot enough to destroy the metal being soldered; a flame that can be adjusted to suit the needs of the job, including a long, slim needle-like flame capable of reaching out-of-the-way places as well as a wide flame for dismantling parts.

b. Gases.—Various gases are used in torches. In fact, there is probably no locality that cannot furnish the facilities for operating a torch. The requirements are a supply of combustible gas under pressure, plus a supply of compressed air or oxygen to make it burn. The air pressure required ranges from 2 to 10 or 12 pounds.

(1) Artificial gas used for cooking and heating in cities is very adaptable to radiator repair work because of its uniformity and concentrated flame, which can be adjusted from a needle flame to a brush flame (fig. 16). The heat is concentrated at the tip of the flame, where the soldering actually takes place.

(2) Hydrogen with compressed air produces a similar flame, adjustable enough to make the torch adaptable to almost any requirement. It is, therefore, very satisfactory when it is available.

(3) Acetylene is frequently burned with air or oxygen in soldering torches. It is not the most satisfactory, however, because as you can see in figure 17, the heat is concentrated near the base, particularly in the brush flame. The greatest heat, therefore, is not where the soldering takes place. With a flame of this type, it is difficult to make certain radiator repairs, even though its length can be varied.

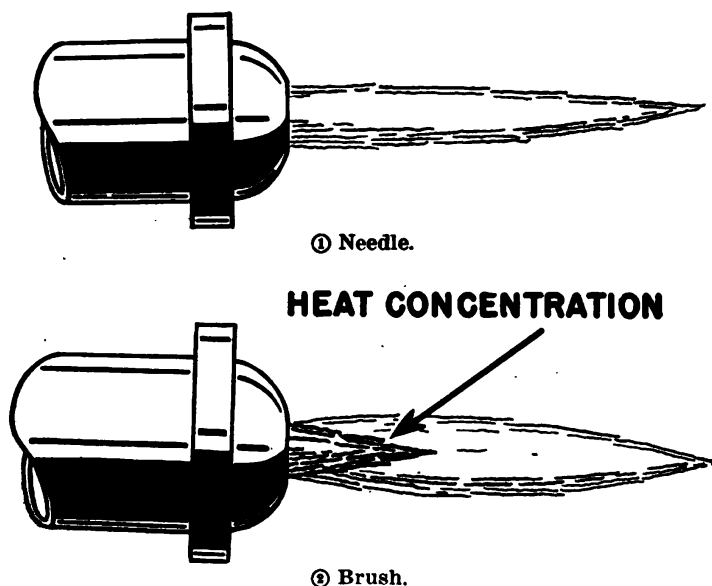


FIGURE 17.—Torch flames, acetylene-air.

(4) Gasoline vapor, produced by passing compressed air through liquid gasoline, is burned in blowtorches. The flames illustrated in figure 18 can be varied widely, the needle flame ranging from 1 to 4 inches long. This wide adjustment makes the blow torch particularly adaptable for radiator repair work.

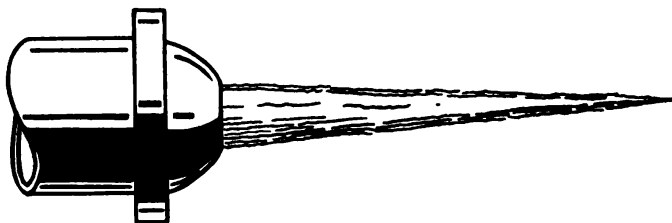
c. Blowtorch.—An ordinary gasoline blowtorch (fig. 19) has a small hand-operated air pump. To fuel the tank, turn the torch upside down, unscrew the cap from the bottom, and fill the tank three-fourths with gasoline. Then after replacing the cap and setting the tank upright, build up a pressure of a few pounds by pumping, which forces a thin stream or spray of gasoline out of the needle hole when the flame adjuster is open. Before trying to start the torch, run a little gasoline into the trough under the burner by opening the flame adjuster valve. Then close the valve and ignite this gasoline which begins vaporizing the gasoline in the burner.

Just before the flame disappears, reopen the valve. The vaporized fuel will immediately produce an extremely hot flame in the burner. From time to time, the air pressure must be replenished.

12. Tinning.—*a.* In addition to tinning the copper (par. 10*c*) the surfaces to be soldered must also be tinned. This tin or “solder coating” is applied to prevent corrosion and aid in soldering. Untinned surfaces must be cleaned with flux before they can be soldered, and even then it is difficult to tell where the solder is not sticking. Tinned surfaces, however, can be sweated together without being fluxed. *No joint should be soldered until the contacting surfaces have been tinned.*



① Needle.



② Brush.

FIGURE 18.—Torch flames, gasoline-air.

b. Old castings or other iron or steel parts can be reclaimed, preserved, and stored for future use by tinning. Clean the part with boiling acid and dip it first in flux and then in melted solder. Immerse the part in solder slowly as the flux will cause the solder to spatter. Allow it to remain until the bubbling ceases, so that all moisture, including acid, flux, and water, is expelled. If untinned spots are found, dip the part again into the boiling acid, which rapidly removes the oxide that prevented proper tinning. Repeat the washing, fluxing, and tinning. Then strike off the surplus solder immediately with a clean rag. It is not essential that the part be tinned by dipping. Either a soldering copper or a torch will produce the same results but not so rapidly.

c. Although copper and brass are easy to clean, it is just as necessary that they be tinned to prevent oxidation. Copper, however, does not take the tinning as well, because it is a good heat conductor and therefore dries the flux rapidly.

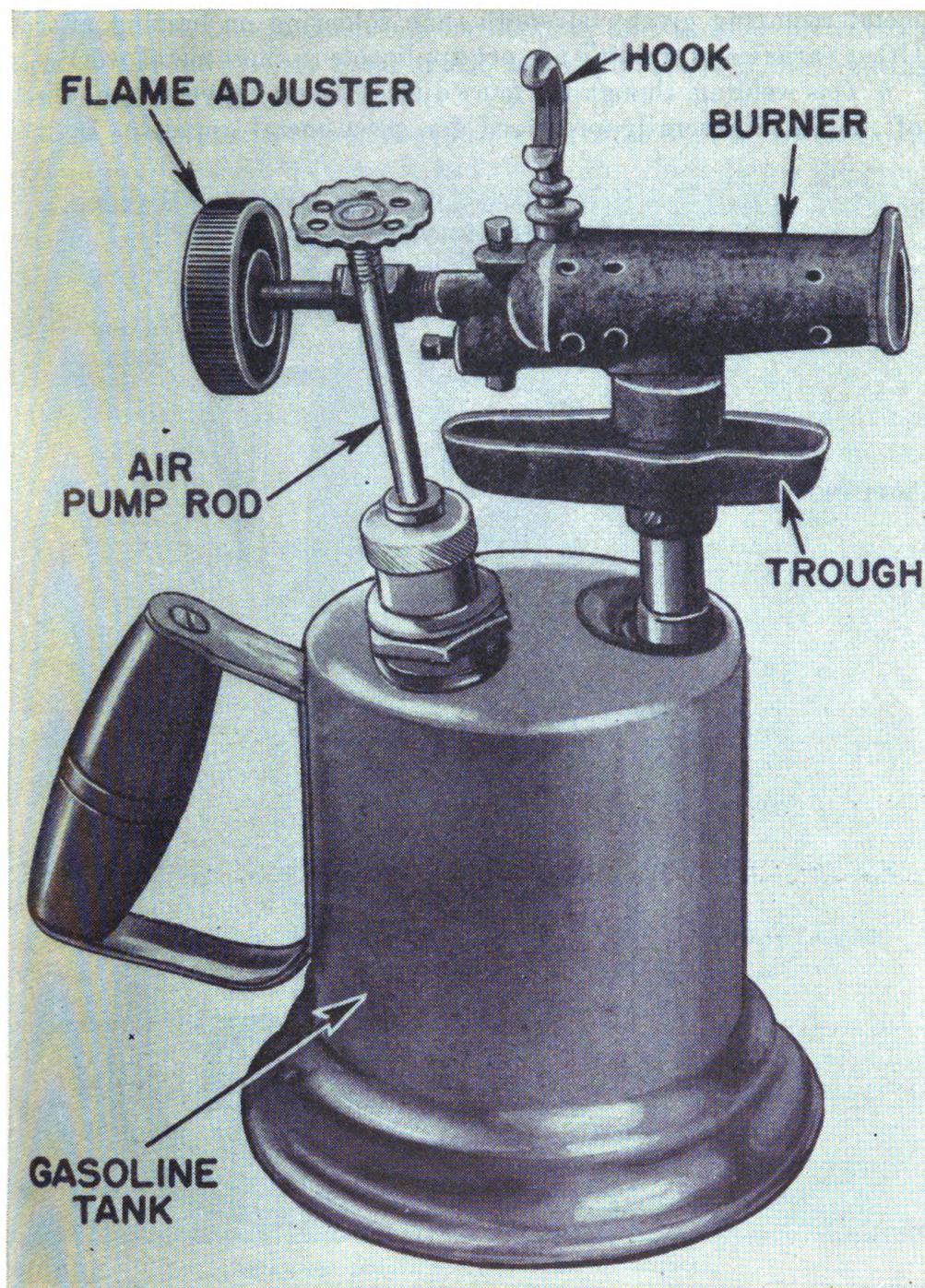


FIGURE 19.—Gasoline blowtorch.

13. Sheet metal welding.—*a.* Although welding is fully discussed in TM 10-440, a discussion of sheet metal work would be incomplete without mention of this important process. Fusion welding by electricity or gas is frequently employed to join pieces of sheet

metal requiring greater strength than soldering or brazing affords. Other varieties of welding are not applicable to sheet metal work.

b. Gas welding, though the more difficult to use on very large sheets of metal, is generally preferred for sheet metal repairs. In both

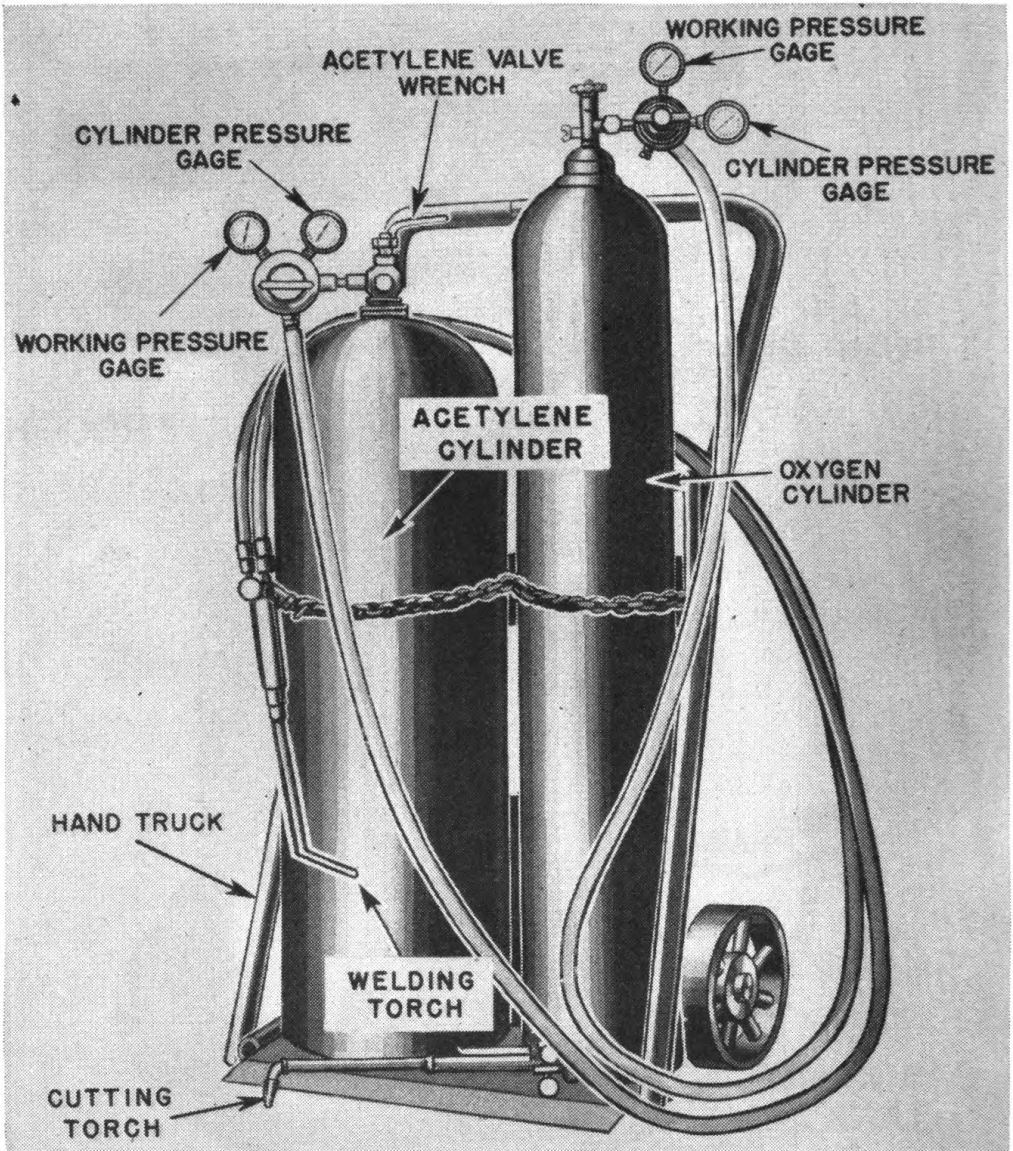


FIGURE 20.—Oxyacetylene welding apparatus.

methods, welding (filler) rod of the same composition as the sheet metal is required for fusing.

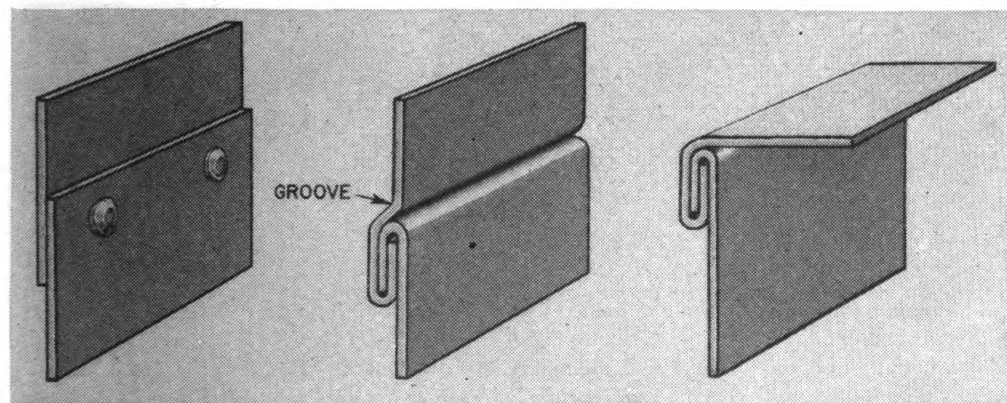
c. A typical gas welding outfit is illustrated in figure 20. Acetylene gas is used as a fuel, with oxygen to support combustion. It is

equipped with two torches: one for welding and another for cutting metal. The two-wheel hand truck facilitates moving the welding outfit near the work.

d. In electric arc welding, the filler rod is often used as one electrode and an arc is struck between it and the work, which forms the other electrode. The metal melts in the arc. Electric resistance and flash welding are used extensively for construction.

e. Good sheet metal welding depends on three principal factors: preparation of the welding edges; correct procedure (adjustment of flame and the use of a suitable welding rod); and location of the weld (design of the article and the use of good clamping devices).

14. Sheet metal seams.—Seaming is one of the most important processes in sheet metal work because a good seam not only joins two sheets of metal, but strengthens the product. The choice of a seam



① Riveted lap.

② Grooved lock.

③ Double lock.

FIGURE 21.—Seams common in sheet metal work.

depends on the equipment available and the strain to be resisted by the product. The seams shown in figure 21 are most commonly used in light sheet metal work. Seams are frequently soldered along the edges to make them watertight.

a. The lap seam used in the construction of small cylinders, squares, pipes, etc., is usually soldered or riveted. When thin metal is used and the seam is to be soldered, allow from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch for overlapping.

b. The grooved lock seam is the most generally used for joining and locking the edges of longitudinal seams of sheet metal. Two single edges are hooked together and flattened with a mallet to make them tight. At this point it is called a common lock seam. For positive assurance against unhooking, the seam is then grooved with a hammer

and hand groover (fig. 22). In some shops, a grooving machine is available for this purpose.

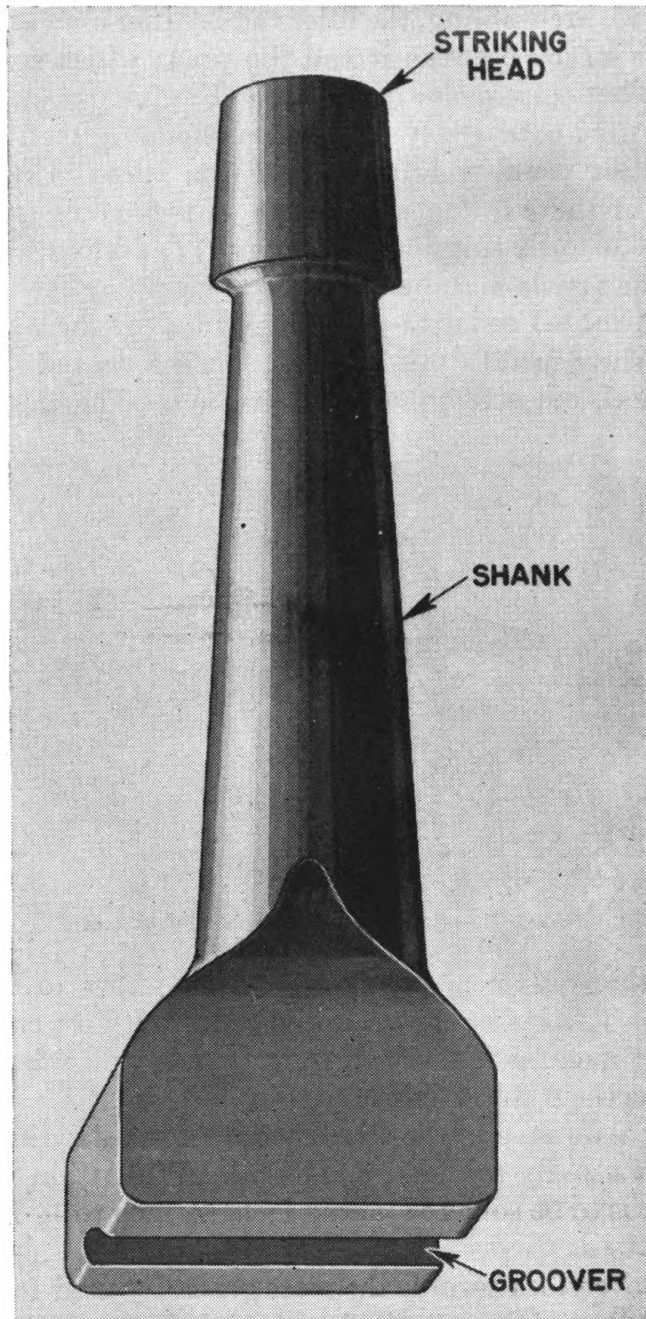


FIGURE 22.—Hand groover.

c. The double lock seam is most commonly utilized in light-gage work to strengthen the bottom of articles. It is formed by hooking two single edges together and bending one edge to make a right angle.

SECTION III

FUEL TANK REPAIR

	Paragraph
General.....	15
Cleaning.....	16
Testing.....	17
Soldering.....	18

15. General.—Fuel tanks for motor vehicles are made of terne plate ranging in thickness from No. 24 (0.0156 inch) to No. 18 (0.050

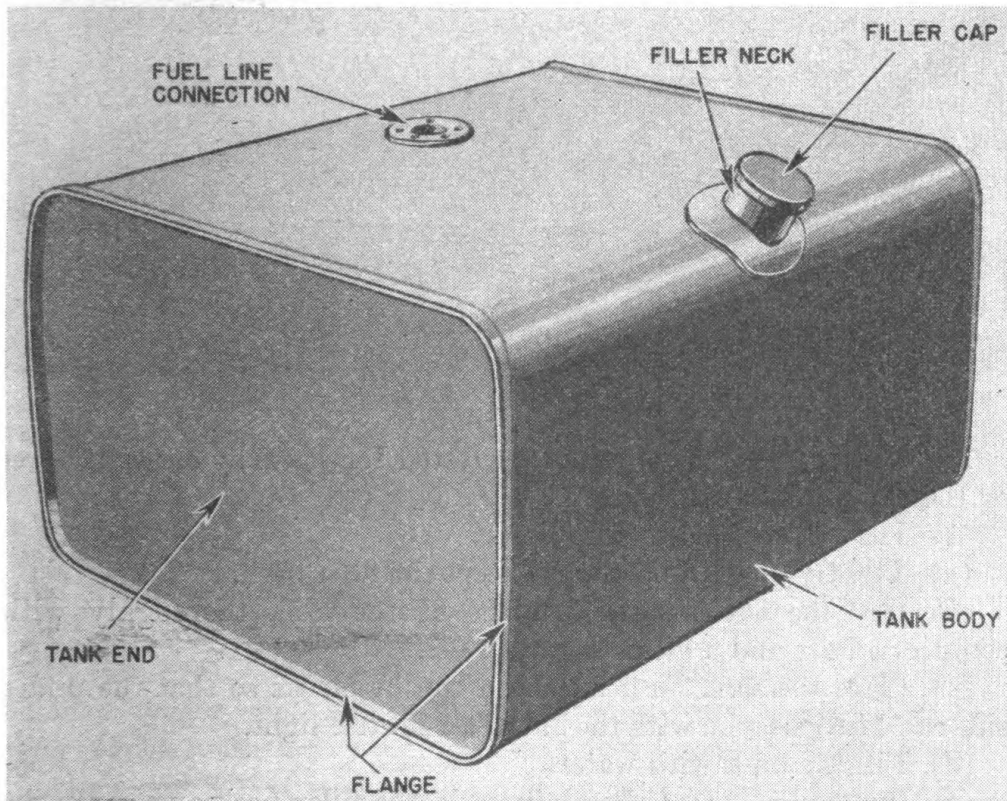


FIGURE 23.—Truck type fuel tank.

inch) U. S. standard gage and joined by welded seams. Fittings such as the filler neck, drain valve, and fuel line connections are soldered to the tank. Baffle plates, inside the tank, offset excessive splashing and foaming of the fuel when the vehicle is in motion. Figures 23 and 24 illustrate two typical constructions. Leaks may occur in the seam welds or soldered joints because of vibration, strain, or faulty construction. Occasional leaks in the tank itself are caused by sharp objects such as stones or bolts, picked up on the road by the wheels of the vehicle and thrown against the tank.

16. Cleaning.—Before attempting to repair any fuel tank, clean the tank thoroughly. This is absolutely necessary as a safety precaution against the explosion of gasoline or fumes remaining in the tank. The usual procedure is to fill the tank with a solution containing an alkaline cleaner (Q. M. C. Tentative Specifications ES-No. 542) and then flush it out with steam. While flushing, keep all the fittings open to drain the sediment and to avoid building up a steam pressure high enough to weaken or wreck the tank.

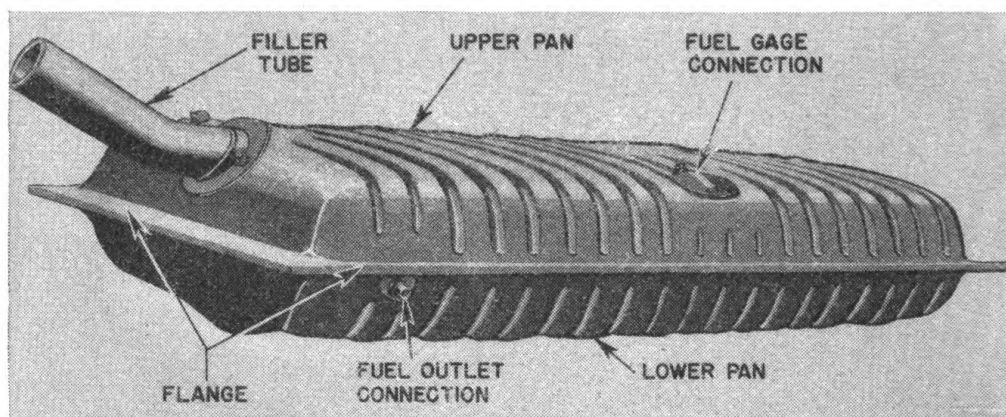


FIGURE 24.—Passenger car type fuel tank.

17. Testing.—*a.* Fuel tanks are tested for leaks by either the wet or the air pressure method.

(1) The wet method is as follows:

(a) Tightly plug all openings except the filler neck.

(b) Dry the entire outer surface of the tank thoroughly with compressed air and a clean rag.

(c) Place the tank on a bench on top of blocks so that the under side can easily be seen with the aid of an electric light.

(d) Fill the tank with water.

(e) Insert the end of the air hose in the filler neck and cover the rest of the opening with the palm of the hand.

(f) Apply air pressure against the water by opening the air valve with the other hand for a few minutes.

(g) Examine the entire tank for moist spots, where the water was forced through.

(2) The air pressure method is as follows:

(a) Plug all openings except the fuel outlet connection.

(b) Attach the loose end of the air supply hose to the fuel outlet connection by a short-threaded tube.

(c) Submerge the fuel tank in a tank of clean water, or cover the tank with soapy water.

(d) Turn on the air pressure, not more than 5 pounds.

(e) Draw a ring around each spot on the fuel tank where bubbles appear. The bubbles indicate leaks.

b. Some tanks stand considerable pressure, whereas others must be handled carefully. A maximum air pressure of 5 pounds with either method of testing is usually sufficient to indicate all leaks. If the tank ends are flat, 3 to 4 pounds air pressure should usually be considered the limit. If compressed air is not available, improvise a method of producing it, such as using an ordinary tire pump.

18. Soldering.—The repair of fuel tanks is a soldering copper job, *not* a torch job, because of the danger of an explosion when an open flame is used. The soldering copper is safe and fast enough if skillfully used. *Never use a torch.* If there are leaks about a fitting, remove it, and clean and retin the joint before resoldering the fitting to the tank. Use half-and-half solder.

SECTION IV

BODY AND FENDER REPAIR

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Analyzing damage.....	21
Metal bumping.....	22
Alinement.....	23
Metal finishing.....	24
Body and fender welding.....	25
Metal shrinking.....	26
Paddle soldering.....	27

19. General.—*a.* The standard all-steel automotive body is assembled by arc, spot, and acetylene welding from strong sheet-steel outer panels with heavy stamped-steel inner construction. Replacing damaged panels is therefore difficult and expensive; and repair is preferred when it is practicable.

b. When a body or fender is damaged by collision, the damage occurs not as one event, but as a series of events in instantaneous succession, such as crumpling, creasing, and ripping, with each event setting up internal strains within the metal. Briefly, sheet metal repair is a two-part process: releasing strains, by reversing the events which caused the damage and restoring the metal to approximately its original shape; and smoothing small irregularities and low spots such as waves, ridges, and pits.

c. Before beginning to study body and fender repairs, study the names by which manufacturers and repairmen commonly refer

to the various sections of the all-steel body and fender (figs. 25 and 26).

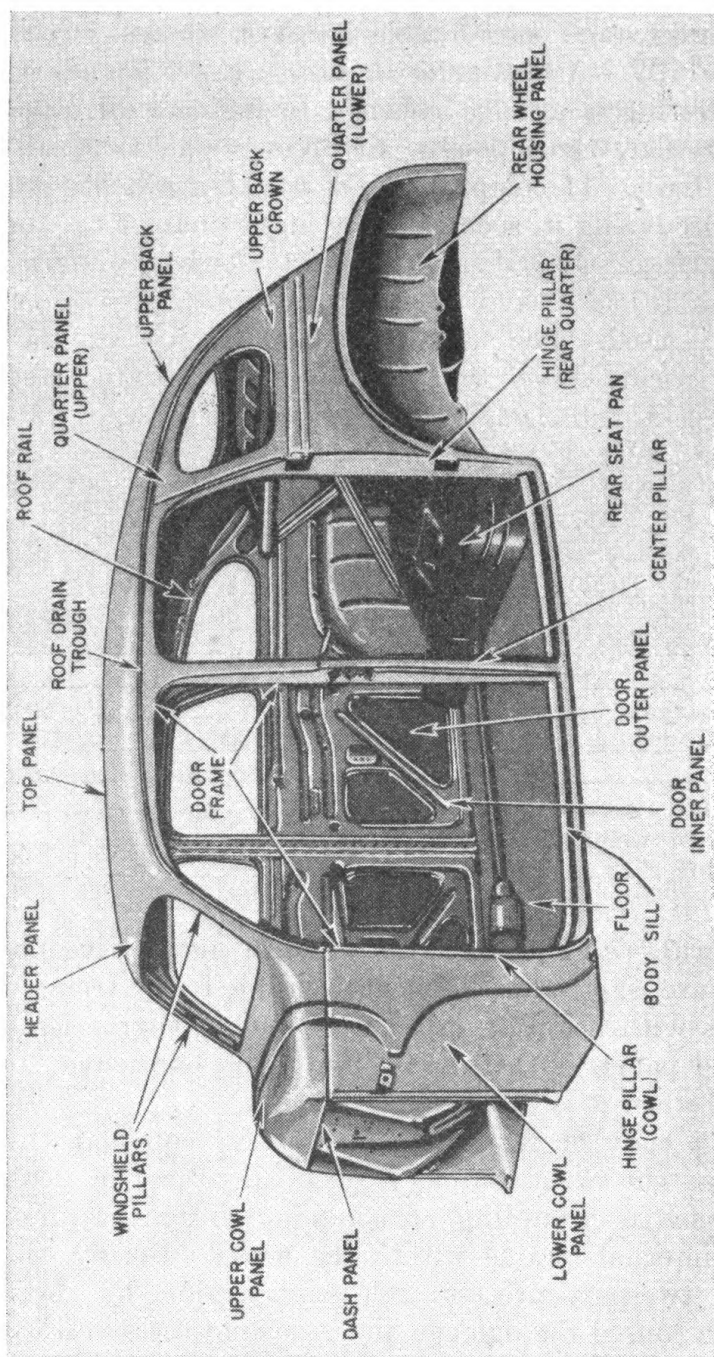


FIGURE 25.—Automobile body nomenclature.

d. To learn body and fender repairing, not only skill with a large number of hand tools must be acquired, but also a study must be made of welding, paddle-soldering, metal-shrinking, and using special

equipment such as the disk sander and the body jack. One thing is certain—no one ever learns it all. A thoroughgoing body repairman is constantly learning new tricks and short cuts no matter how many years of experience he has behind him.

e. Beginners will make many mistakes. That is to be expected. If the mistakes are recognized and analyzed, however, the beginner will learn much faster than if he admits no wrong.

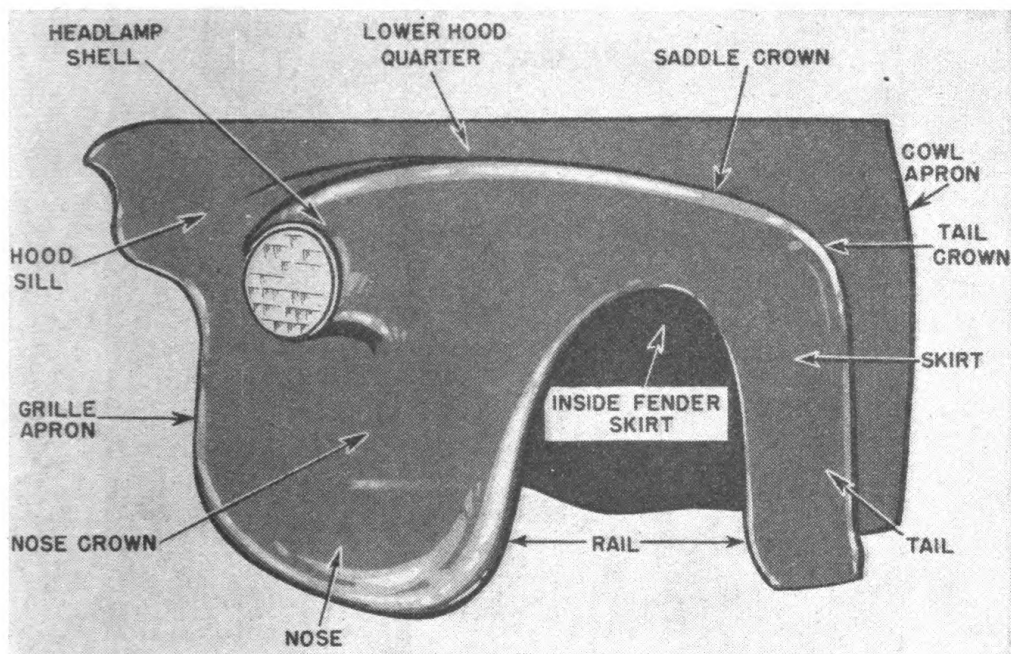


FIGURE 26.—Automobile fender nomenclature.

20. Basic tools.—Body panels or fenders can be straightened either with hand tools or with special power-driven equipment. Because each maker of power-driven tools supplies the instructions necessary for using them, this manual will cover in detail only the basic hand tools: the hammer, dolly, and spoon. Around their use the whole science of body and fender repair has developed.

a. Hammers.—(1) Figure 27 illustrates a bumping hammer and figure 28 a dinging hammer. Bumping hammers which range from 14 ounces to about 2 pounds in weight are used for heavy, roughing-out work, whereas dinging hammers weighing about 9 or 10 ounces are used for lighter finishing work. Because the bumping hammer has crowned faces, it should be used on the inside of crowned surfaces, whereas the flat-faced dinging hammer is used on the outside, as shown in somewhat exaggerated form in figures 29 and 30. Obviously a flat-faced hammer used on a concave surface as in figure

29 would nick the top surface at the points marked *X*. Likewise, a round-faced hammer used on the convex surface in figure 30 would dent it at *X*. Referring again to figures 27 and 28, note that both the bumping and dinging hammers have round and square heads

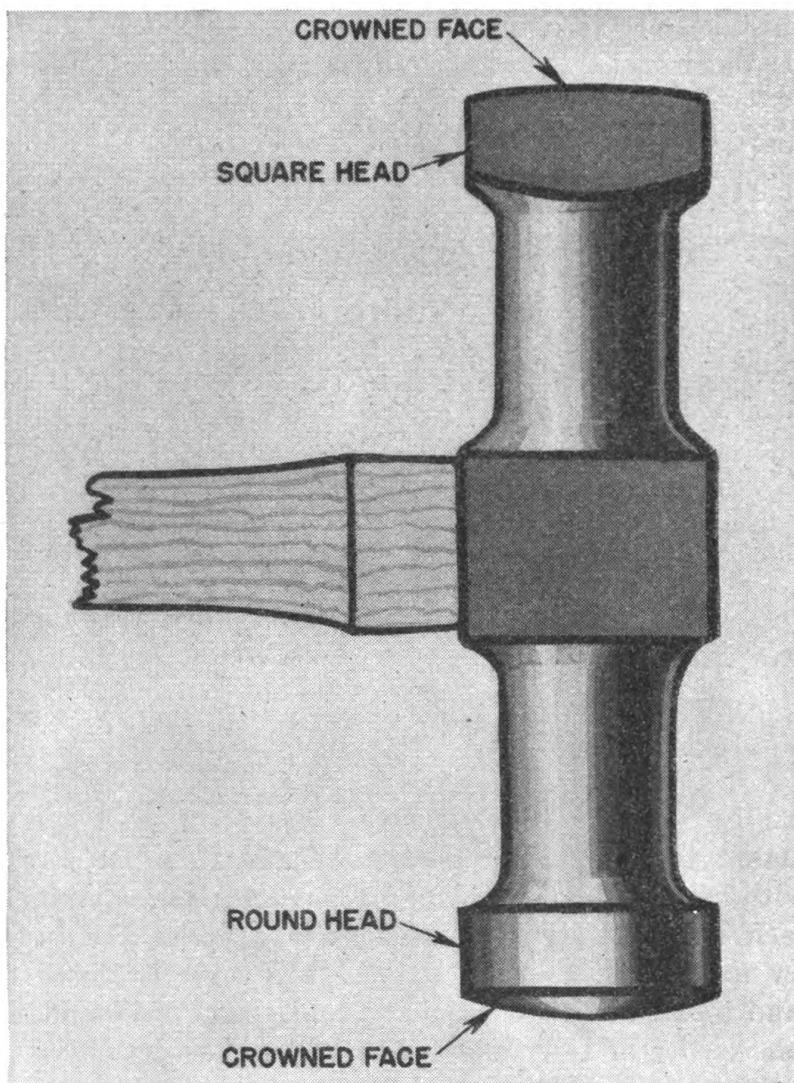


FIGURE 27.—Bumping hammer.

on opposite ends. This is to accommodate different shapes of work, the square face being used along straight lines, the round one against rounded corners.

(2) Hammers of peculiar construction are available in various weights for special jobs. Use a long-headed hammer (fig. 31) for working into deep-crowned fenders and body braces; a half-hammer

(fig. 32) where only a short swing is possible; and a fender bumper (fig. 33) for bumping fender dents.

(3) A rubber mallet can sometimes be used to straighten a panel without seriously damaging the finish.

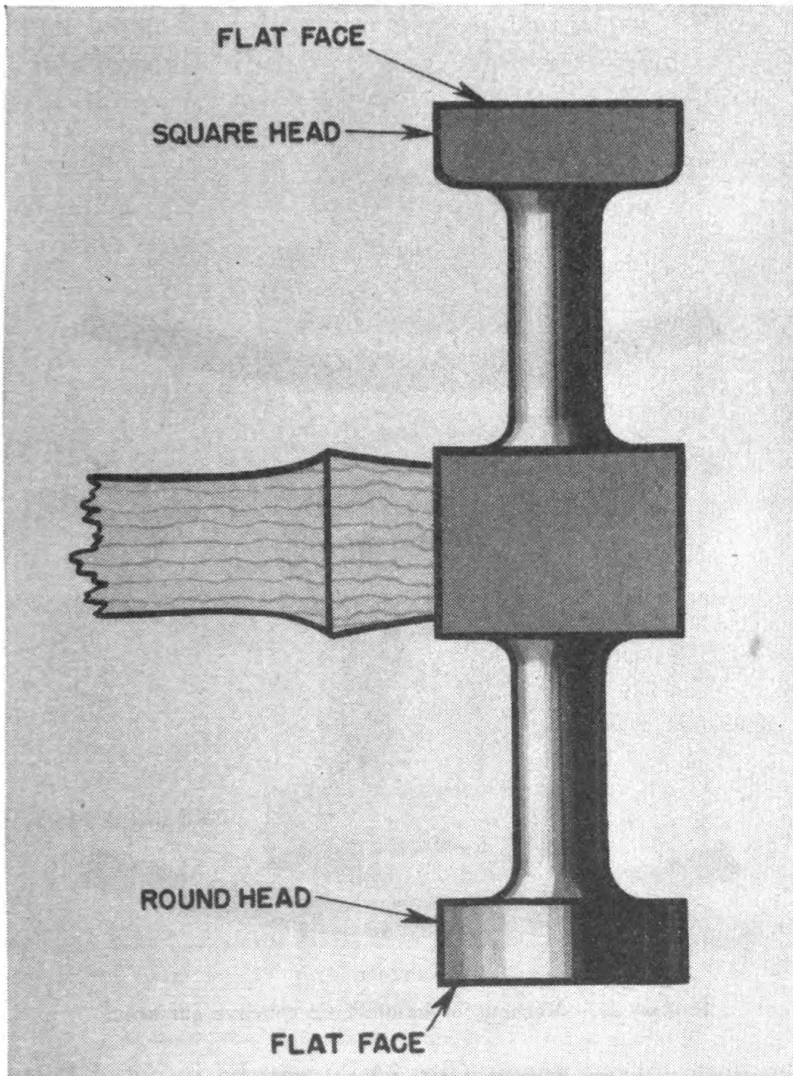
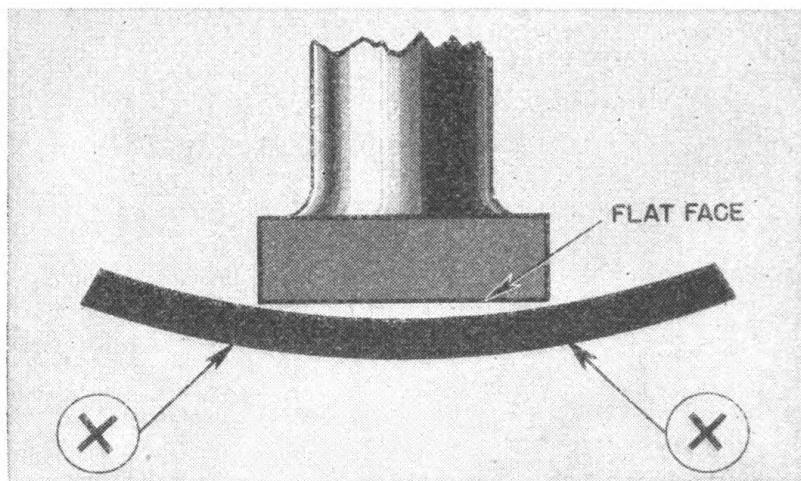


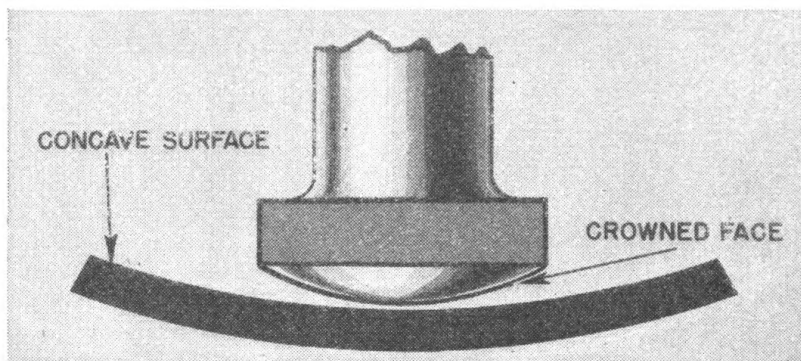
FIGURE 28.—Dinging hammer.

b. Dolly blocks.—Dolly blocks are small anvils with hardened, finished faces, constructed so that they can easily be held in the hand to back up metal as it is hammered. Their shapes, contours, and sizes are so numerous that they fit almost all the unusual curves and angles in the bodies and fenders of modern motor vehicles. Several typical dolly blocks and their uses are shown in figure 34.

c. *Spoons* (fig. 35).—Spoons are used like dolly blocks in removing dents from places otherwise inaccessible, as between fenders and brackets or behind upholstery. A spoon may also be placed over a dent and struck with a hammer to remove the dent. By distributing the force of the blow, it protects the finish from damage.



① Incorrect.



② Correct.

FIGURE 29.—Methods of hammering concave surfaces.

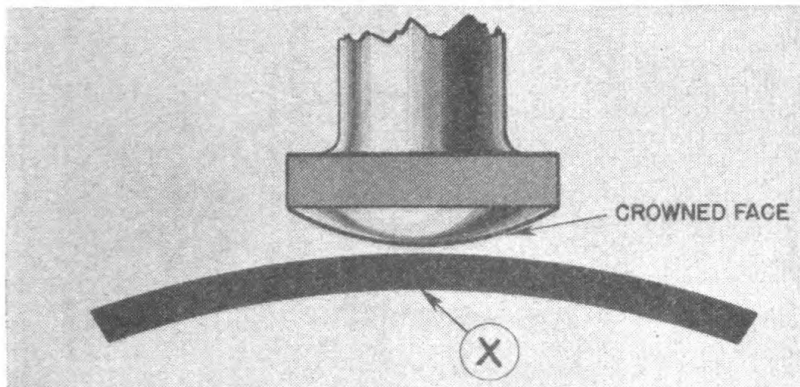
(1) The long curved spoon (fig. 35①) can be inserted between the inner construction and outer panel and hammered on the end to raise low spots to their original level. The tip of the blade can be used as a medium-crowned calking face when hammer blows are directed against the outside of the bend. The spoon can also be used as a pry or as an offset dolly for dinging behind reinforcements.

(2) The heavy body spoon (fig. 35②) is similar to the long curved spoon, but its shorter, more curved blade makes it more adaptable in cramped places.

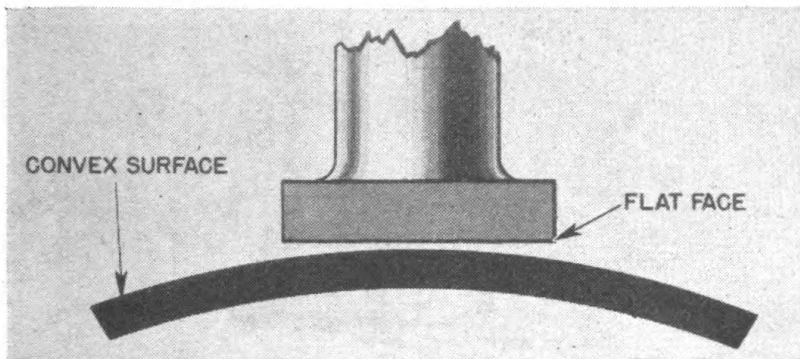
(3) The offset blade spoon (fig. 35③) is used where curved spoons do not conform to the shape of the body.

(4) Long and short spoons (fig. 35④ and ⑤) with straight polished blades are used for dinging or prying out large depressions.

(5) The wide panel spoon (fig. 35⑥) is used to avoid cracking the paint finish when straightening large indentations. Place it on the painted surface and tap it with the hammer instead of striking the metal directly.



① Incorrect.



② Correct.

FIGURE 30.—Methods of hammering convex surfaces.

(6) The combination spoon (fig. 35⑦) is a general-purpose spoon with a long, high-crowned face for working behind reinforcements on high-crown panels. It is particularly adapted for working between fender brackets and fender metal where a dolly block is useless.

d. Bending irons.—Bending irons as the name implies are designed for bending brackets, flanges, and aprons. They are used less frequently than the hammer, dolly, and spoon.

e. Polishing hammer and dolly faces.—When hammers or dolly blocks become scratched, the scratches must be removed to avoid dam-

aging painted or lacquered surfaces. Rub out the cratches on a fine oilstone and polish the faces. Fine emery cloth (as well as most other abrasives) is too coarse for polishing hammer and dolly faces. The following procedure, however, yields excellent results: On a piece of $\frac{7}{8}$ -inch poplar about 4 by 10 inches in size and smooth on

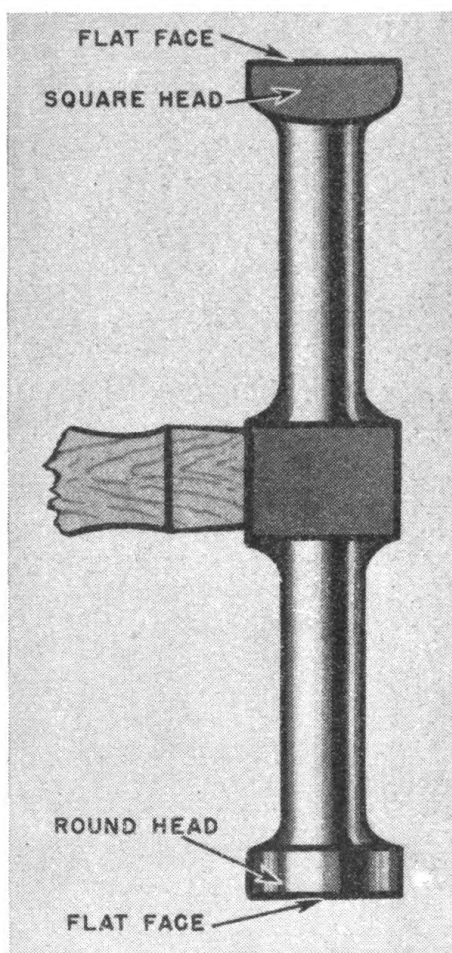


FIGURE 31.—Long-headed hammer.

one side, prepare a polishing abrasive paste by moistening hydrated lime with denatured alcohol. Rub the hammer or dolly faces on this board until the original polish is restored. Take care to preserve the original contour of the faces.

21. Analyzing damage.—*a.* This is a step in body and fender repair that cannot be overemphasized. To repair swiftly and surely, it must be known where the damage stopped, for this is the point at which work should begin. The job is somewhat like untangling a

fishline; the knots are rather easily untied in the reverse order of their occurrence. On the other hand, a planless approach in un-snarling fishlines or removing body and fender damage makes the work increasingly difficult and time-consuming.

b. Although no two damaged panels or fenders look exactly alike, in every case the damage consists of a buckled-up series of ridges and

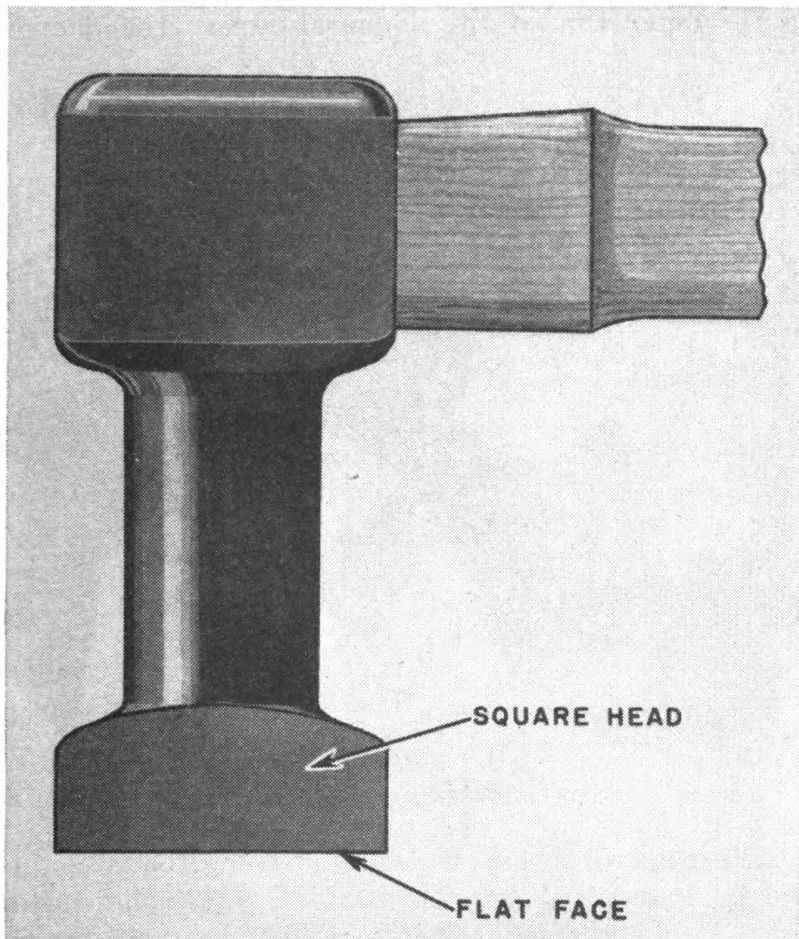


FIGURE 32.—Half-hammer.

V-shaped channels, large or small, forced successively into the panel by the colliding object. Often such damage resembles a wheel. The point of impact is the hub; the pushed in V-channels are the spokes; the outer ridge is the rim. Smaller damages can be likened to a section of a wheel.

c. A slow-motion picture of a panel being damaged would show the colliding object at first denting the panel only slightly. Then, as the object continued its destructive force, a larger area would cave

in. At the same instant a ridge would buckle up at the edge of this larger area, because the curved metal cannot collapse or telescope and must go somewhere as it passes through the chord of its original arc, as shown in figure 36. As the colliding object travels farther across the panel or deeper into it, this high, buckled-up ridge travels ahead of the crumpling metal, much as a wave travels ahead of a boat. When the damage is completed, the ridge remains locked in place, forming the outer rim of the damaged area. The damaged area

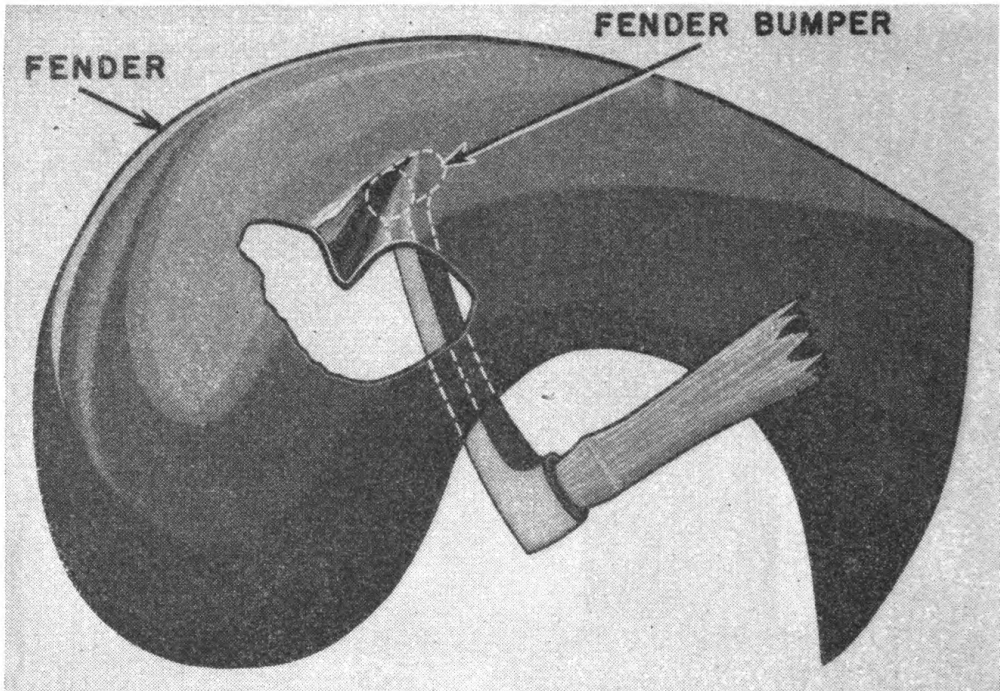


FIGURE 33.—Using a fender bumper.

springs back somewhat, but it remains strong, because the locked ridge and the inverted V-channels reinforce it, as rims and moldings reinforce the sides of a pail. The various ridges and channels thus block repair of the damage, but they cannot be smoothed out until the major strains in the locked ridge have been released, as shown in figure 37.

d. To remove this series of distortions in reverse order, first determine from which direction the damaging force came and then locate the last ridge which was buckled up. Then visualizing the damage as it passed through its various stages, the sequence of the strains can be tracked down.

22. Metal bumping.—After analyzing the damage, the next step in body and fender repair is metal bumping, the important unlocking

and unrolling operation. If this is done carelessly or hurriedly, new lines of strain will probably be set up, stretching and bending the metal at such sharp angles that a further rearrangement of the displaced fibers will be impossible.

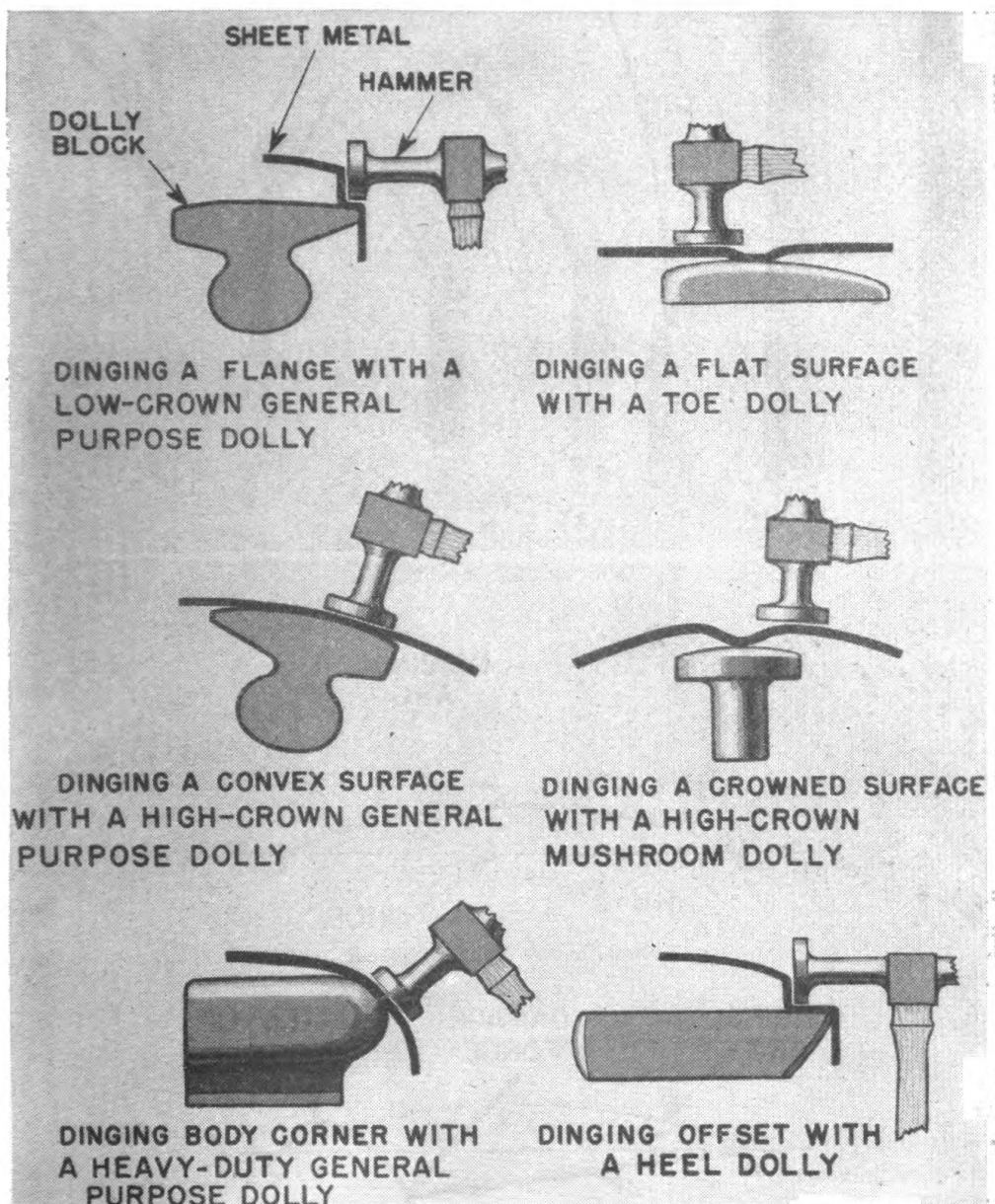


FIGURE 34.—Using dolly blocks.

a. Preparation.—(1) Before repairing fenders, scrape off any tar, gravel, or road dirt from underneath the damaged part. Any dirt left on the under side will cake on the dolly block, so that hammering smooth will be impossible.

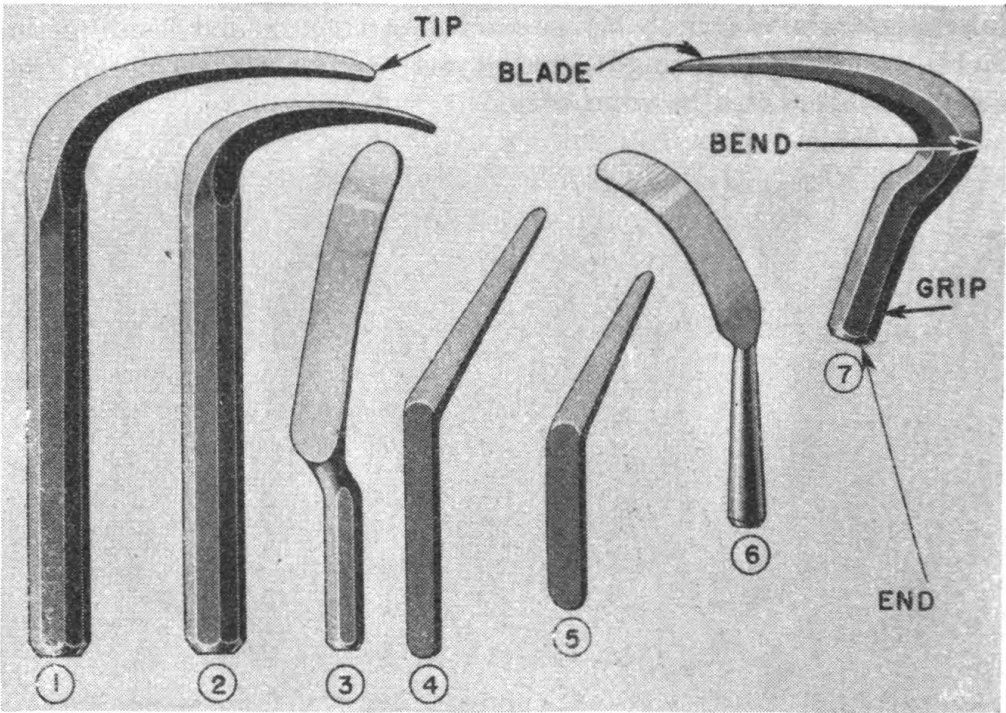


FIGURE 35.—Spoons.

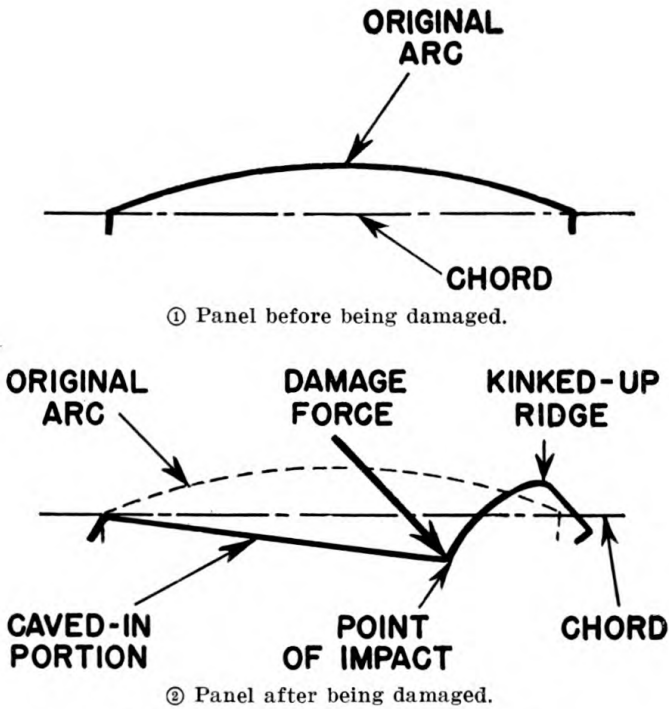
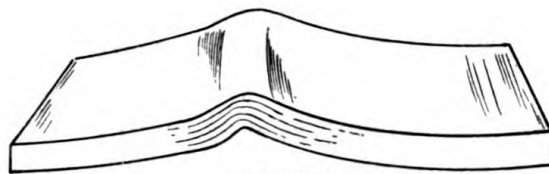
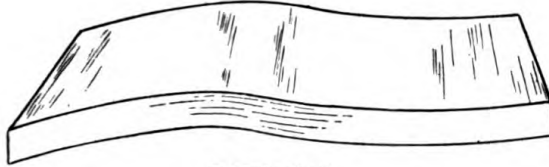


FIGURE 36.—How simple damage occurs.

SHEET METAL WORK AND REPAIRS



① Locked.



② Unlocked.

FIGURE 37.—Ridge of metal.

(2) Next, wipe the outside surface of the damaged fender or panel with a rag and a little thin motor oil. This removes dust and grit which would otherwise stick to the hammer face and hinder the worker from securing a smooth surface. The light reflected from the oiled surface shows the extent and depth of the various bumps.



FIGURE 38.—Illuminating damaged surface by light reflection.

(3) It is sometimes helpful to lay a full-width newspaper on the floor about a foot ahead of the damaged body or fender panel, and place a light on it as in figure 38. Move the light back and forth until a direct reflection on the metal surface highlights the damage when standing back of it and looking toward the light. It is very important to watch the exact spots of the damage. Trying to locate all

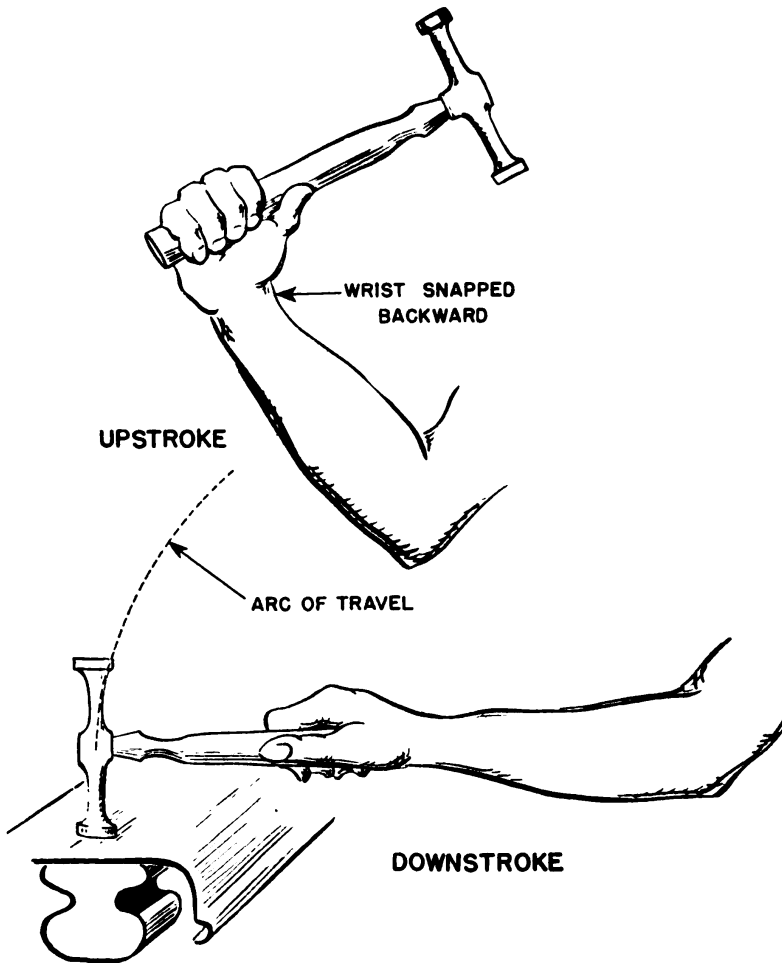


FIGURE 39.—How to grasp and swing hammer.

the high and low spots by rubbing the hands over the damaged surface gives poor results and wastes time as well. Wavy surfaces are the result of guesswork.

b. Art of hammering.—(1) Since metal bumping and finishing are simply a matter of hammering, it should be learned at the outset how to use the hammer and dolly. The simple secret is to make every blow of the hammer strike the metal directly above the dolly or spoon.

(2) A good carpenter uses a free whipping stroke to drive nails straight and fast. A good golfer uses a free whipping stroke to drive a ball far and straight. The same stroke is best for bumping and dinging. A free whipping blow is accomplished by letting the arm and wrist swing freely, as illustrated in figure 39. Grip the hammer well back on the handle just tightly enough to keep it from rolling in the hand, because a long grip requires less effort to swing the hammer than does a short grip. On the upstroke, practically all the movement of the arm is from the elbow to the wrist. At the top of the stroke, snap the wrist backward sharply, bringing the hammer head to a quick stop. Start the downstroke with the wrist

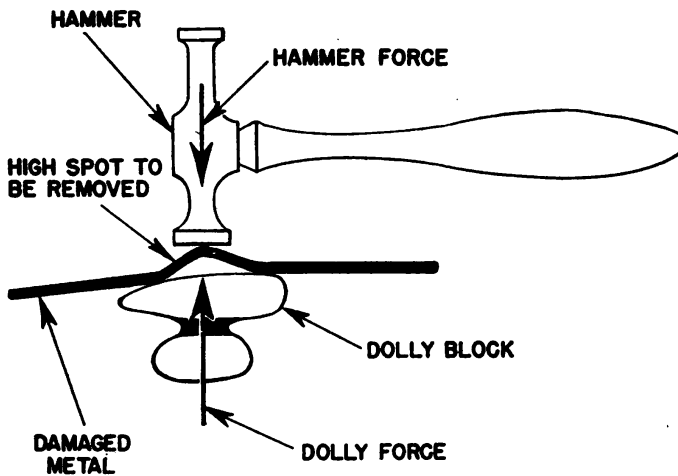


FIGURE 40.—Using hammer and dolly.

relaxed, and let the weight of the hammer head snap the wrist over quickly, directing the hammer in a perfect arc. Then, without forcing the muscles, a hard, easily controlled, free whipping blow will be struck. Using a short choked grip, however, propels the hammer with a stiff-arm movement that reduces power and control.

(3) A simple application of the use of a hammer and dolly block is shown in figure 40. The downstroke of the hammer drives the high spot down onto the face of the dolly block, smoothing the metal. The dolly block absorbs the shock of the hammer blow and prevents the damaged metal from being driven down too far. At the same moment, the dolly block bounces away from the under surface of the damaged metal and quickly rebounds against the low spots, raising them before the next stroke of the hammer. With free whipping blows of the hammer on the outside surface of the metal, the two hand tools rapidly smooth the rough spot.

(4) Never grip the dolly tightly or apply any great amount of pressure on it, for the important automatic bounce-and-rebound of the dolly will be lost. Most repairmen naturally develop a rhythm of 60 to 150 successive hammer blows per minute as they become skillful.



FIGURE 41.—Simple damage.

c. Metal bumping process.—This is only a matter of hammering the high spots down and bringing the low spots up until the damaged metal is again even in contour. Note the sequence of this statement. Putting the *high metal down first* is very important. The following discussion will explain why.

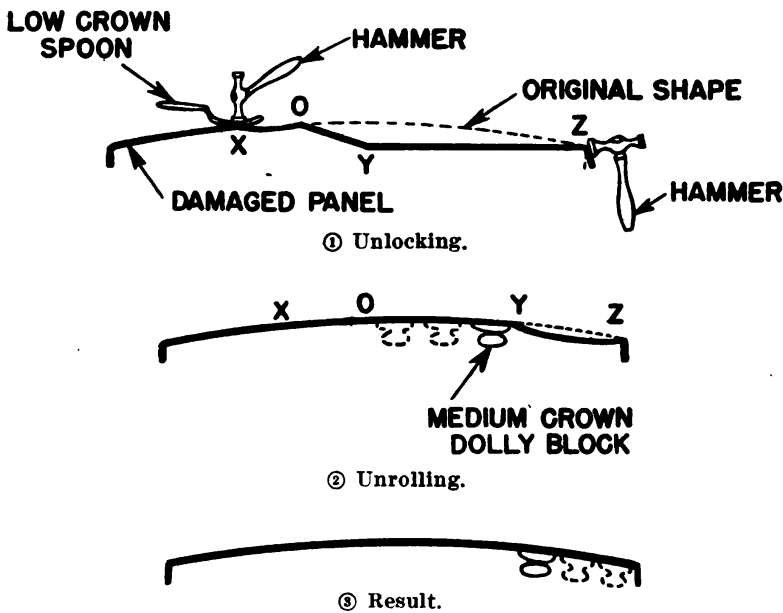


FIGURE 42.—Removing simple damage correctly.

(1) Figure 41 illustrates a simple damage which may occur to an outer door panel. The arrow indicates the direction of the damaging force. *X* marks the outer rim of the damaged area and *Y* marks the point of impact or the hub. The line *XY* represents a cut at the bottom of one of the V-channels. *Z* marks the flanged edge of the panel, which has been bent sharply by the panel's collapse. It is also locked.

(2) Since ridge *X* is clearly the last created in the damage, it is the first strain to be unlocked. Place a low-crown dinging spoon on it as in figure 42① and hammer the spoon sharply, directing the blows straight at the ridge. This unlocks the high metal and moves it back toward its original position. Next, ding the flange corner *Z*, unlocking it. The areas of metal between *O* and *Y* and between *Y* and *Z* are now lying unlocked, ready to spring back to normal shape with very little help. Give this help with a medium-crown dolly block, as in figure 42②, unrolling the wave with two or three blows on the under side from *O* through *Y*. This unlocks the kinked metal at the bottom of the V-channel *OY*. Repeating this procedure from *Z* to *Y* restores the metal to the position shown in figure 42③.

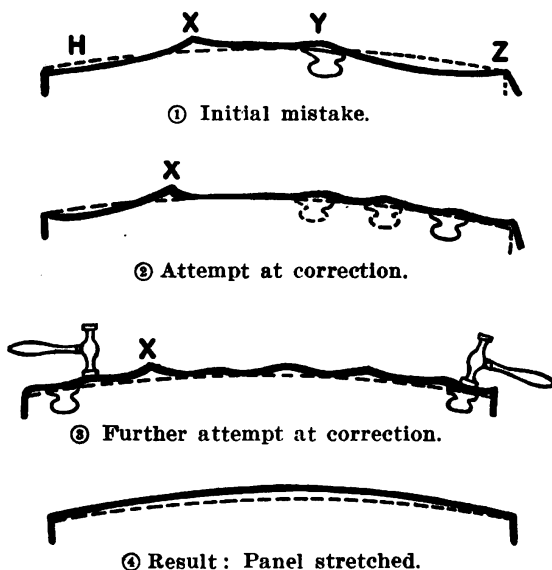


FIGURE 43.—Removing simple damage incorrectly.

(3) Figure 43 illustrates the error of roughing out the same damage without first releasing the locked ridges. In figure 43① the caved-in metal is being roughed out by striking the underside at *Y* with a dolly. This forces up a large area of the dent to nearly its normal shape. Note, however, that the strain in the ridge *X* has not been unlocked; the ridge does not come down to its normal place, but instead pulls the panel down abnormally at *H*. This happens because the locked ridge *X* has reinforced and strengthened the metal on either side of it. When force is applied upward at *Y*, therefore, the ridge acts as a fulcrum, pulling the metal down at *H* as it is forced up at *Y*.

(4) Now that roughing out has been started without releasing the locked ridge, the metal must be stretched to raise it to its original level,

indicated by the dotted line. So much force is now required to bring it up to place, that it humps and knots wherever it is struck by the dolly block, as shown in the second view. Equalizing all these humps and knots means a lot of work. In figure 43③ the dent has been roughed out, and the hammer and dolly are in place to start smoothing.

(5) In figure 43④, the dent is restored to a normal shape. Note, however, that it is a new shape. Not only has time been wasted in unplanned bumping, but the metal has been stretched, as shown by the dotted lines, so that the entire width of the panel, instead of only the damaged area, requires metal finishing.

d. Calking.—When the wheel opening of a fender has been hit directly on the flanged edge by the bumper of another vehicle, the flanged edge is forced back into the skirt of the fender, folding the



FIGURE 44.—Straightening flanged edge of damaged fender with calking iron.

metal accordion-like. Use an offset calking iron to repair this kind of damage, as in figure 44. Hook one end around the fender into the flange and drive it back with one or two blows of a hammer. Removing the wheel is not necessary.

e. Damaged rear trunk lid.—(1) Figure 45 shows a damaged rear trunk lid, which at first glance seems very difficult to metal bump or repair. The damage consists of a large wheel-shaped dent with three channels as the spokes—*X*, *Y*, and the *V*-channel, which is the deepest crease. Point *X*, where a license plate bolt was pushed into the panel, is obviously the focal point of the damage.

(2) The *V*-channel may quickly be dismissed from consideration as the direction of the damaging force, not only because there is no high, buckled-up ridge on the opposite side of the damaged area, but because the *V*-channel normally should be at right angles to the damaging force, and not in its path. This leaves arrows *X* and *Y* as the possible directions of the impact.

(3) Assume for the moment that the colliding object came from behind, struck the trunk at *X*, and traveled toward *Y*. It would then have left a characteristic high, buckled-up ridge beyond *Y* at the edge of the damage marked by the numeral 1. Finding the ridge, the assumption is considered to be correct.

(4) As a check, however, assume now that the colliding object fell on the trunk at *Y* and traveled downward to *X*. In this circumstance, a high, buckled-up ridge at point 6 would be expected, but

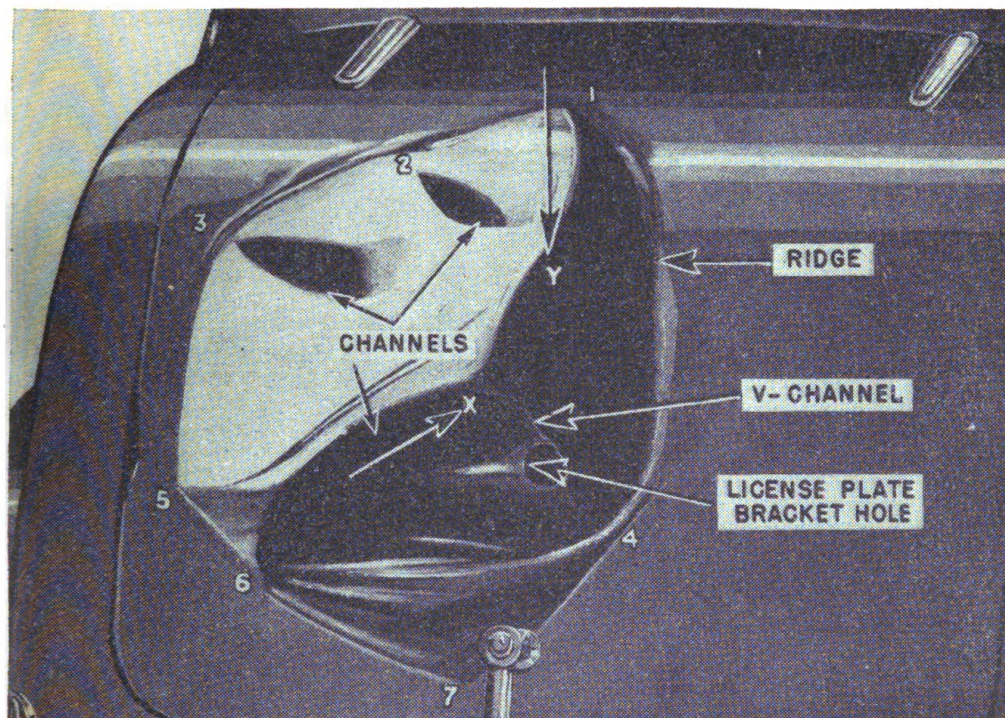


FIGURE 45.—Crushed rear trunk lid.

the ridge at that location is actually much smaller than at point 1. This assumption is therefore false; arrow *X* correctly indicates the direction of the damaging force.

(5) The first ridge to unlock this time is clearly No. 1. Then the ridges numbered 2, 3, 4, 5, 6, and 7 (reversing the order in which they were created) should be dinged out before any caved-in metal is bumped. Figure 46 pictures the trunk lid after the ridges have been dinged down with a dinging hammer and a low-crown spoon. Note that at this stage the only repairing has been done from the outside. Only high metal has been hammered.

(6) With the damage strains formed by these ridges now unlocked, the strains formed in manufacture by dies can unroll a part

of the damaged area. The metal is kept from completely resuming its normal shape, however, by the damage strains locked in the channels.

(7) To unlock them, force a heavy spoon between the jammed inner construction and outer panel, as near as possible to *1*, on a direct line from *Y* where the die-formed strains are strongest. This unlocks the channel leading to point *X*. The V-channel is the deepest, but it is unlocked in the same way. As the channels are released successively, the entire damaged area springs out almost to its normal shape.

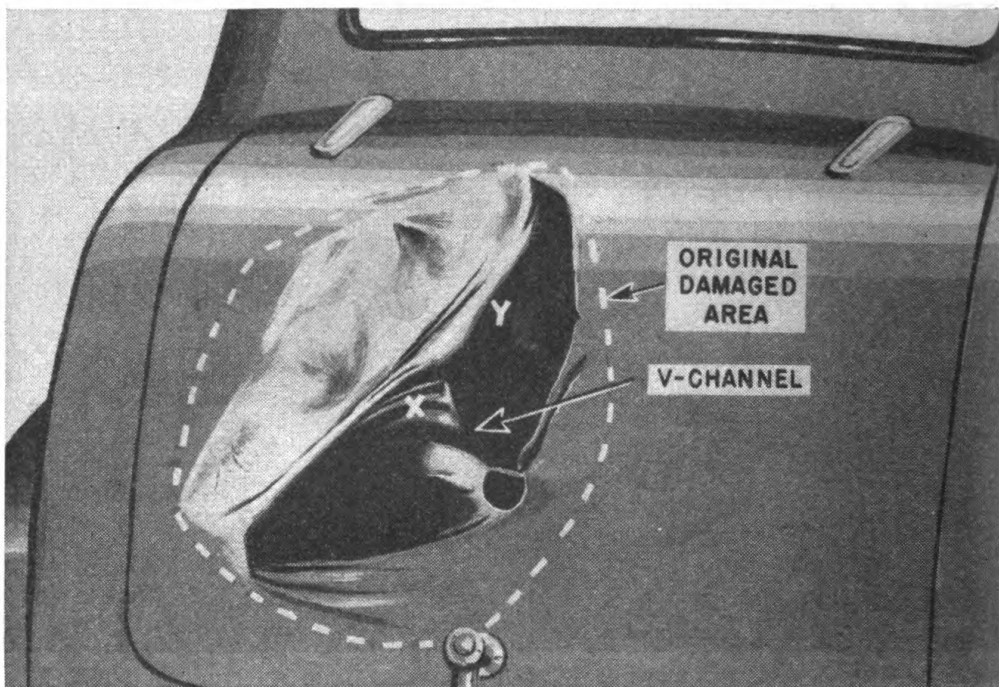


FIGURE 46.—Trunk lid with ridges dinged down.

(8) To complete metal-bumping the trunk, insert a heavy spoon between the inner and outer panels as in figure 47. Use it to pry the outer panel, meanwhile working against it with a dinging hammer around the dent. All the traces of high ridges 3, 5, 6, and 7 are thus removed without damage to the paint.

(9) Notice that the area which requires metal finishing is only about 90 or 100 square inches, as shown by the smaller dotted outline of figure 48. Furthermore, the metal has not been stretched by bumping; the only section which will require shrinking is spot *X*, where the license plate bolt was forced through the trunk lid.

(10) If the damage had been bumped by "roughing out" and "smoothing up," without regard to the order of the locked ridges,

an area of 600 or 700 square inches as inclosed in the layer outline would have required metal shrinking and finishing. The inner construction might have had to be cut out and welded in again. Certainly the job would have required at least three times as much time, not to mention a large quantity of expensive materials such as disk sanders, files, sandpaper, surface thinner, and paint for finishing.

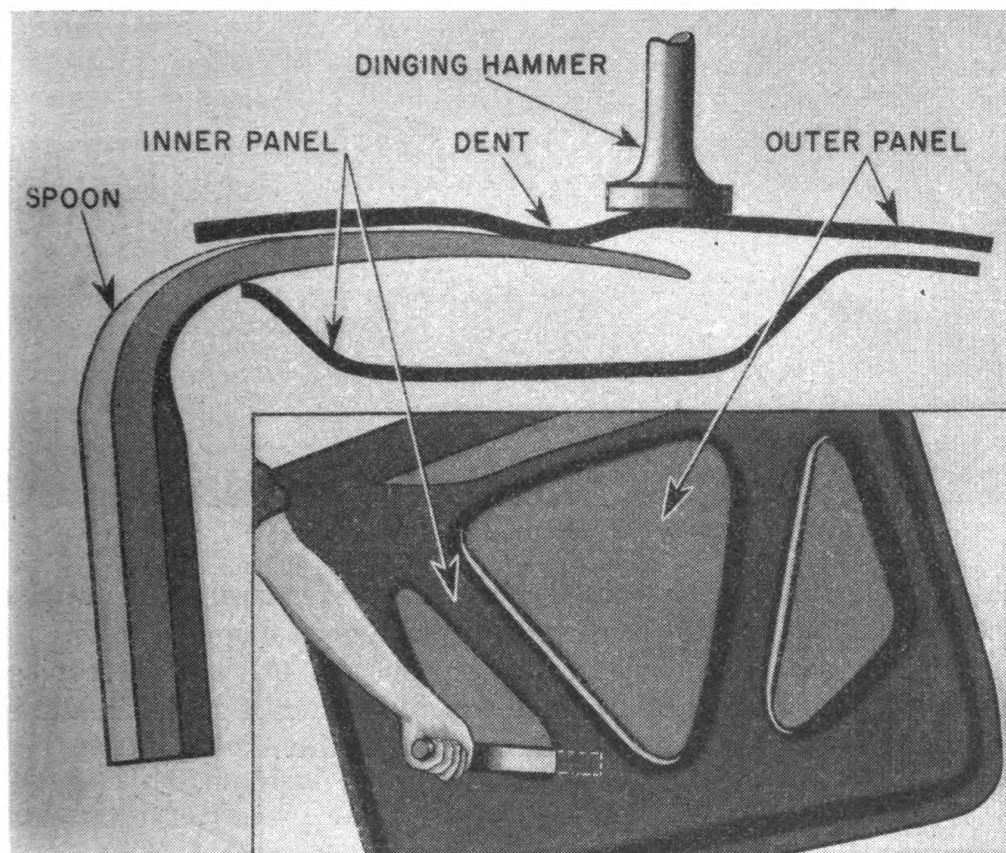


FIGURE 47.—Unrolling damage with spoon.

23. Alinement.—Alinement is squaring the damaged body of a motor vehicle by restoring its correct shape and dimensions. Since this is a major repair operation, it is usually done by the fourth echelon. Misalignment may be checked by observation, but measurements are more accurate.

a. Checking alinement.—(1) The best measuring method of checking, known as **X-checking**, is simply an application of the principle that the diagonals of a true rectangle will be equal in length. Some areas that must be checked, such as door openings, the front section (area between the cowl hinge pillars), and the center section (area

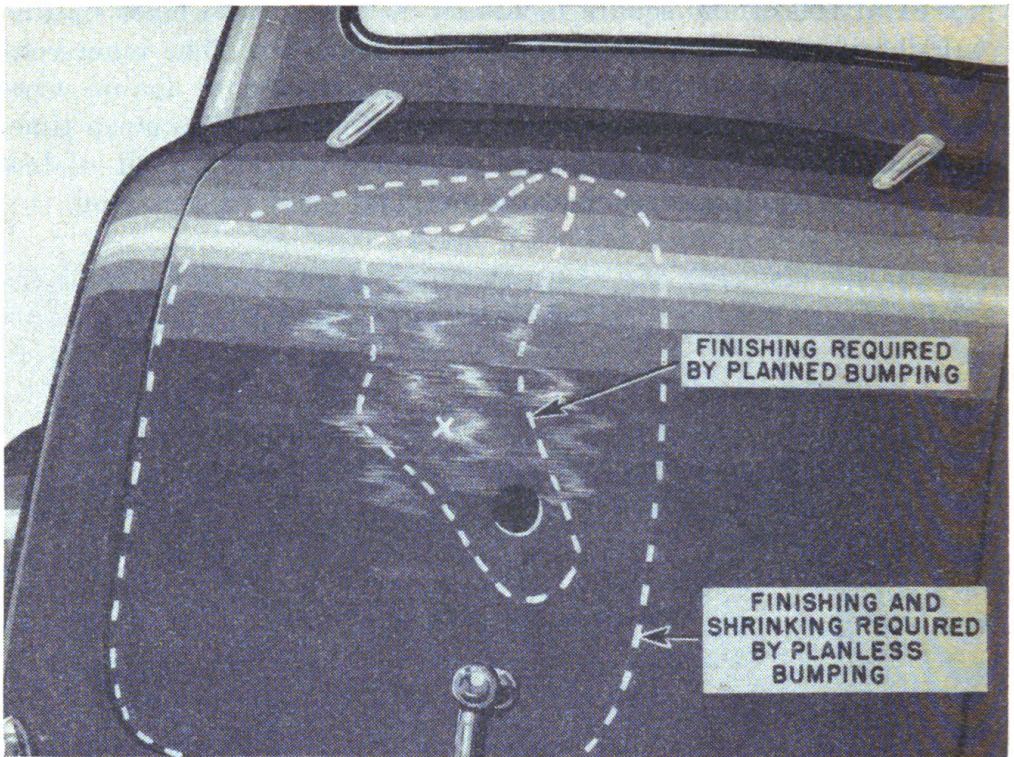


FIGURE 48.—Penalty of planless bumping.

between the center pillars) are not in themselves square, but rectangles may be laid out within them which provide good diagonal tests.

(2) The measuring device, called a tram (fig. 49), is a telescoping tube equipped with an extension clamp which fixes it at the measurement of one diagonal for comparison with another.

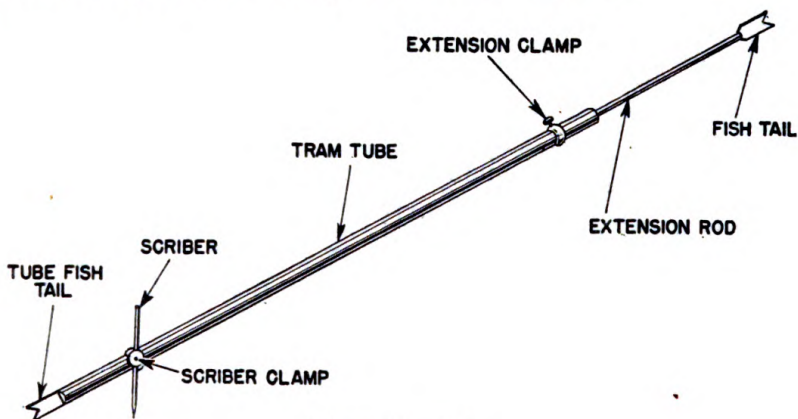


FIGURE 49.—Tram.

(3) Since most severe collisions distort the frame as well as the body of the motor vehicle, the frame must be checked and straightened first. Divide it into three rectangles, using as corners the front

and rear spring shackles, as in figure 50. Then lay the tram at diagonal AB' , clamping it at the exact length of the diagonal. Remove the tram and check $A'B$ to see whether this length is the same. In the same way, check BC' against $B'C$ and CD' against $C'D$. If there is any deviation of measurements, do not check body alinement until corrective forces have been applied, as described in paragraph 23*b*, to bring the frame into line.

(4) Misalinement of a door opening in a body is generally checked by the fit of the door. However, it may also be checked by the tram as shown in figure 50. Here measurements are taken by marking off a distance X along the center pillar from B to C and a distance Y along the body sill from B to A . Set the tram with its ends on

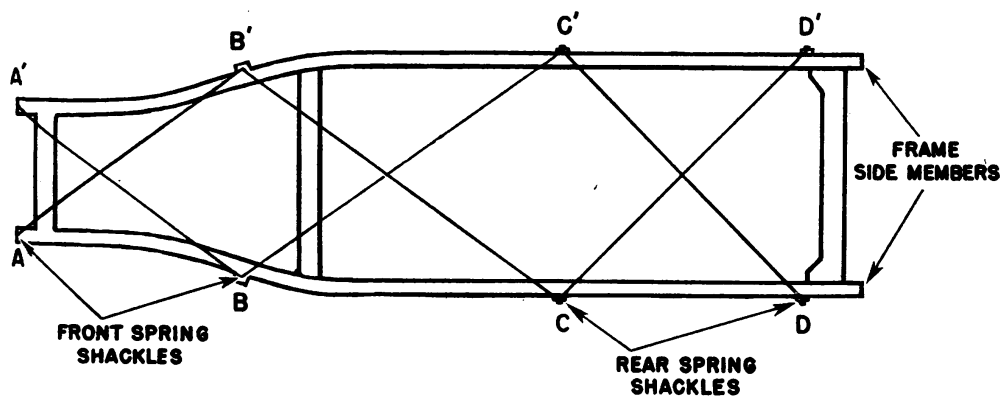


FIGURE 50.—X-checking frame alinement with tram.

points A and C and compare this length with similar points on the undamaged side of the vehicle or on a similar vehicle. Any misalinement of the door opening will be indicated by the necessity of resetting the tram.

(5) If both sides of the vehicle are damaged, lay out a rectangle such as $ABCD$ (fig. 51) in a correctly alined door opening of a similar vehicle. Then measure the distances X and Y and transpose these measurements to the door opening of the damaged vehicle. If the diagonals AC and BD are not equal, the door opening is out of alinement.

(6) After the door openings on both sides of the vehicle have been checked, measure the front section in the same manner. In this measurement, the same points A and D as before are used, together with points F and E in corresponding positions on the opposite door openings, to form the corners of a rectangle (fig. 52). The diagonals AE and DF should be equal. If they are not, the misalinement must be corrected before other checks are made on the body.

(7) Because the front section is logically divided into two rectangles, one above the instrument panel and one below, each of these should next be tested separately to determine whether the instrument panel is in line (fig. 53). This time points *G* and *H* are located at corresponding top-hinge bolt heads on the opposite cowl hinge

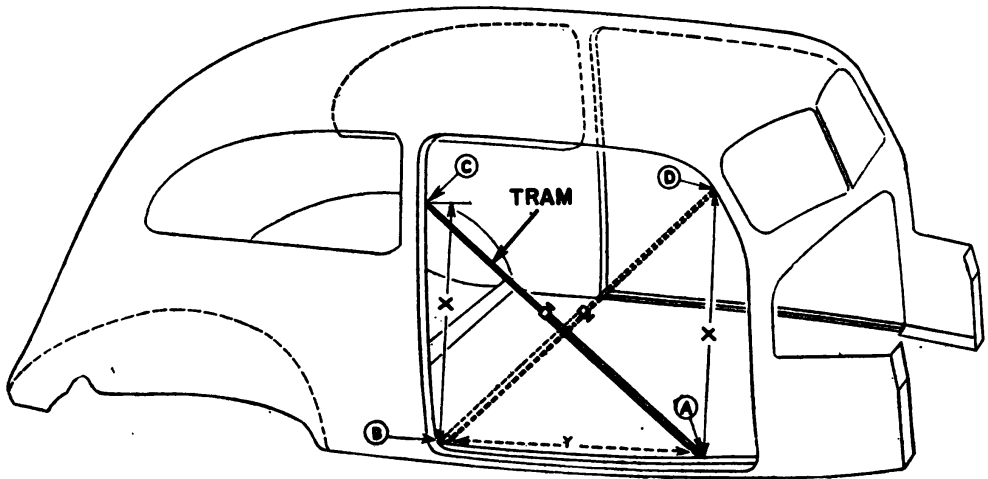


FIGURE 51.—X-checking door-opening alignment with tram.

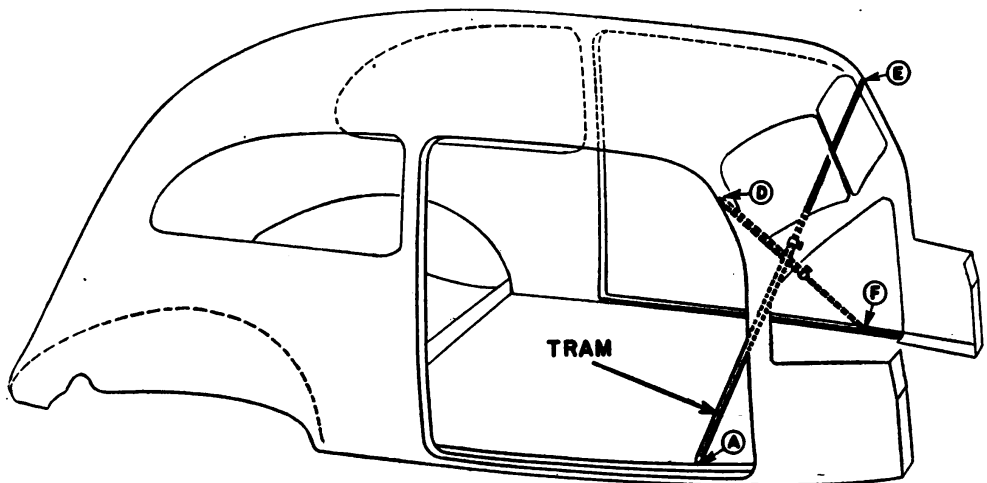


FIGURE 52.—Checking front-section alignment.

pillars. The test is now made just as before with the tram, which this time should show diagonals *EG* and *DH* to be equal, and *GF* and *AH* to be equal.

(8) The center section is tested twice. First, points *I* and *J* (fig. 54) are located on the opposite door corresponding to points *C* and *B* of the door-opening test. The diagonals *BI* and *CJ* must be equal. Then points *K* and *L* are located at corresponding loca-

tions in the middle of the center pillar, such as the pressed molding in the body panel. If the tram shows BL and JK to be equal, center alinement is satisfactory.

(9) The last test to be made in a coach-style body is a check of the front section against the center section (fig. 55). For this test,

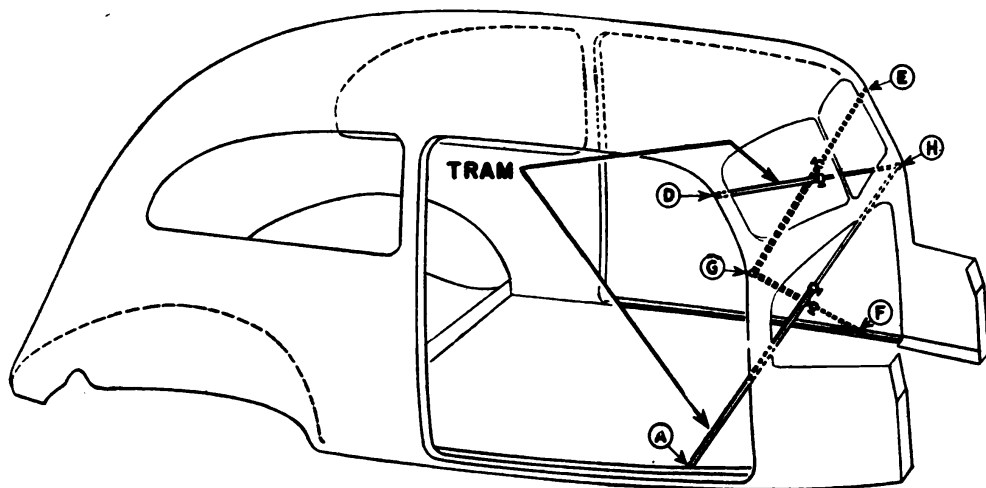


FIGURE 53.—Checking instrument-panel alinement.

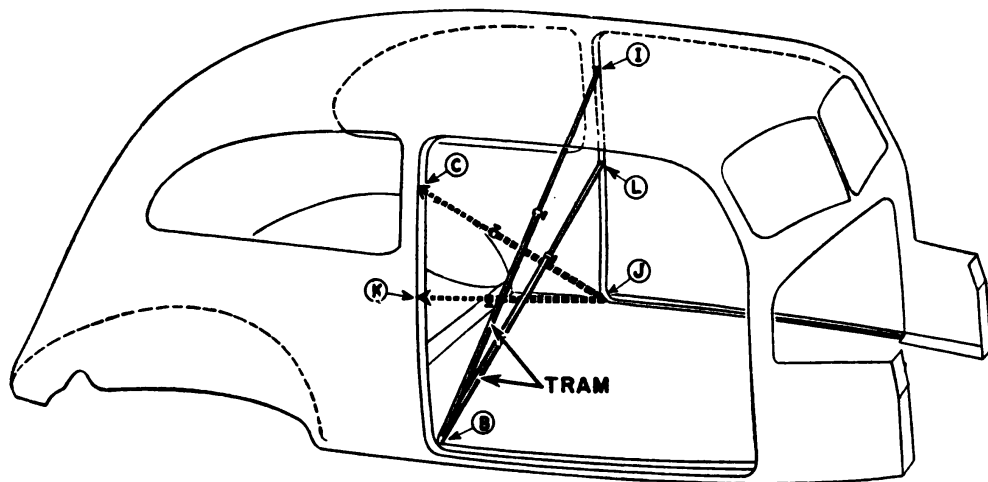


FIGURE 54.—Checking center-section alinement.

no new points need be located; the tram is merely used to compare measurement AI against CF , and BE against DJ .

b. Correcting alinement.—To correct collision damage in a motor vehicle requires a strong force opposite to the direction of the impact. Powerful portable jacks have, therefore, been developed to replace crowbars, planks, and other makeshifts that were used for years to force damaged frames and bodies back into shape.

(1) The portable hydraulic jack shown in figure 56 is capable of exerting a 10-ton force. It consists simply of a hydraulic cylinder connected to a hand pump through a hose. It is provided with at-

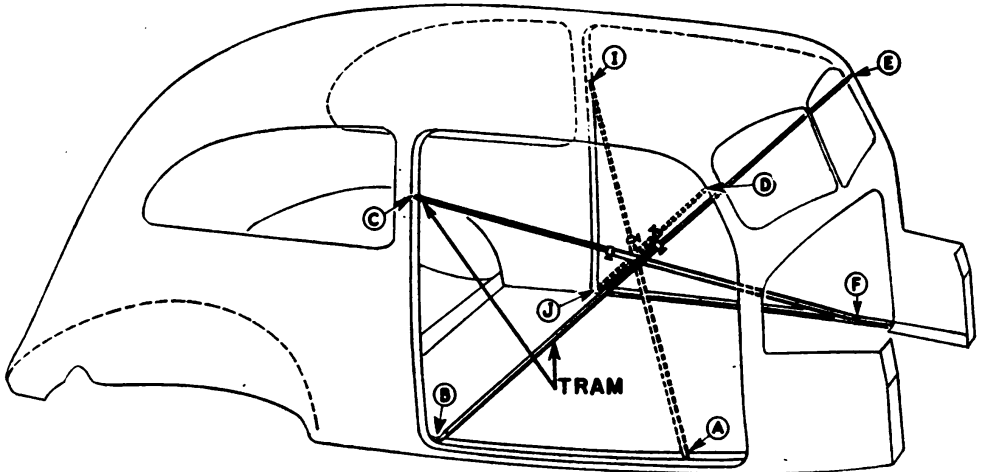


FIGURE 55.—Checking alinement of front section against center section.

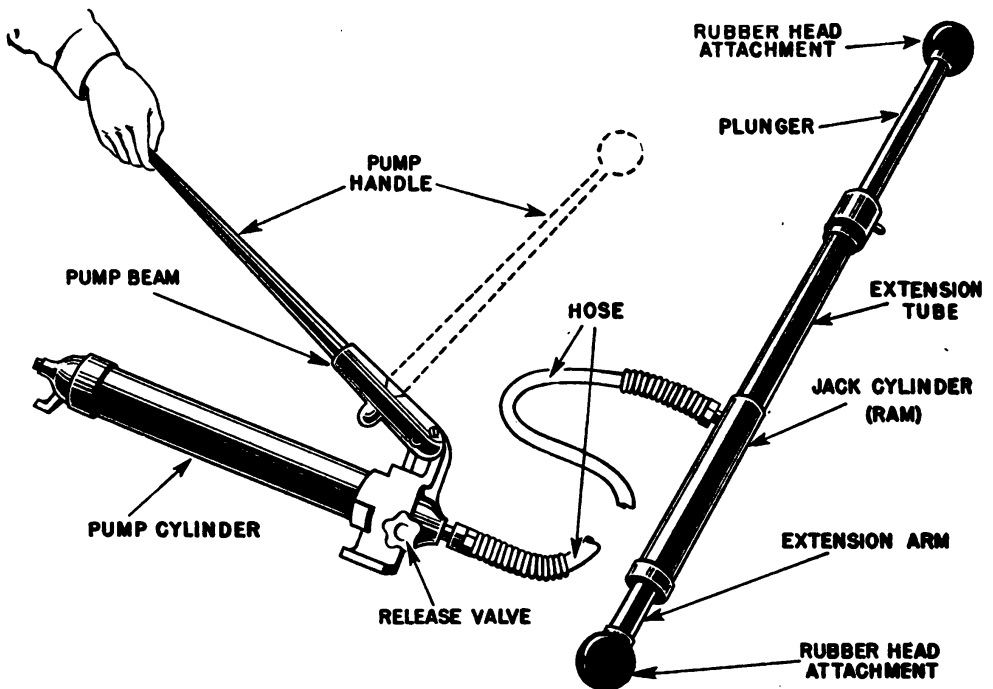


FIGURE 56.—Portable hydraulic jack.

tachments for pushing, pulling, bending, clamping, or spreading, which can be used singly or in combinations. Screw them onto the base or top of the jack cylinder or onto the plunger.

(a) Before using the jack, size up the job to determine the direction of the damaging force. If the frame has been twisted, align this first, removing the body to get at it if necessary. Make a set-up using the ram and its attachments to apply hydraulic force reversing the force of the damaging impact.

(b) To operate the jack, insert the handle into the pump beam either horizontally or vertically. Close the release valve, turning it by hand as far as possible to the right. The downstroke of the

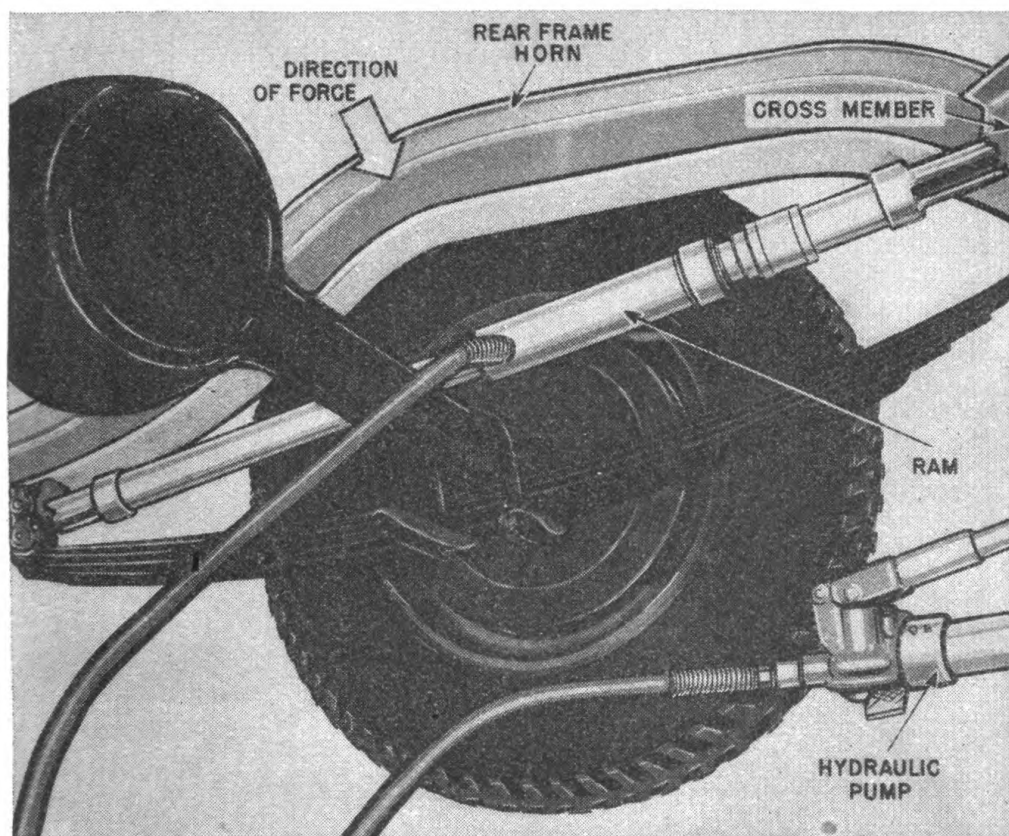


FIGURE 57.—Stretching bent rear frame horn.

handle forces oil through the hose to the ram, causing the plunger to travel outward under pressure. To release the pressure, turn the release valve on the side of the pump to the left.

(c) Figures 57 to 59 illustrate applications of the hydraulic jack in straightening frames. In figure 57 a spreading combination is shown stretching the rear frame horn into proper curvature. Figure 58 shows an attachment for straightening the front frame horn with the toe of the ram anchored to a reinforced section of the frame. Figure 59 shows a bent frame channel easily pulled into line with

a chain pull plate attachment, a short wooden beam, and two blocks. When the frame is perfectly alined and the body alinement carefully checked, apply the jack to straightening the body. Never attempt to straighten an all steel body off the frame; always remount it and bolt it firmly.

(d) Figure 60 shows how to force out a body dent with a hydraulic jack by working gradually around it toward the center. A door frame

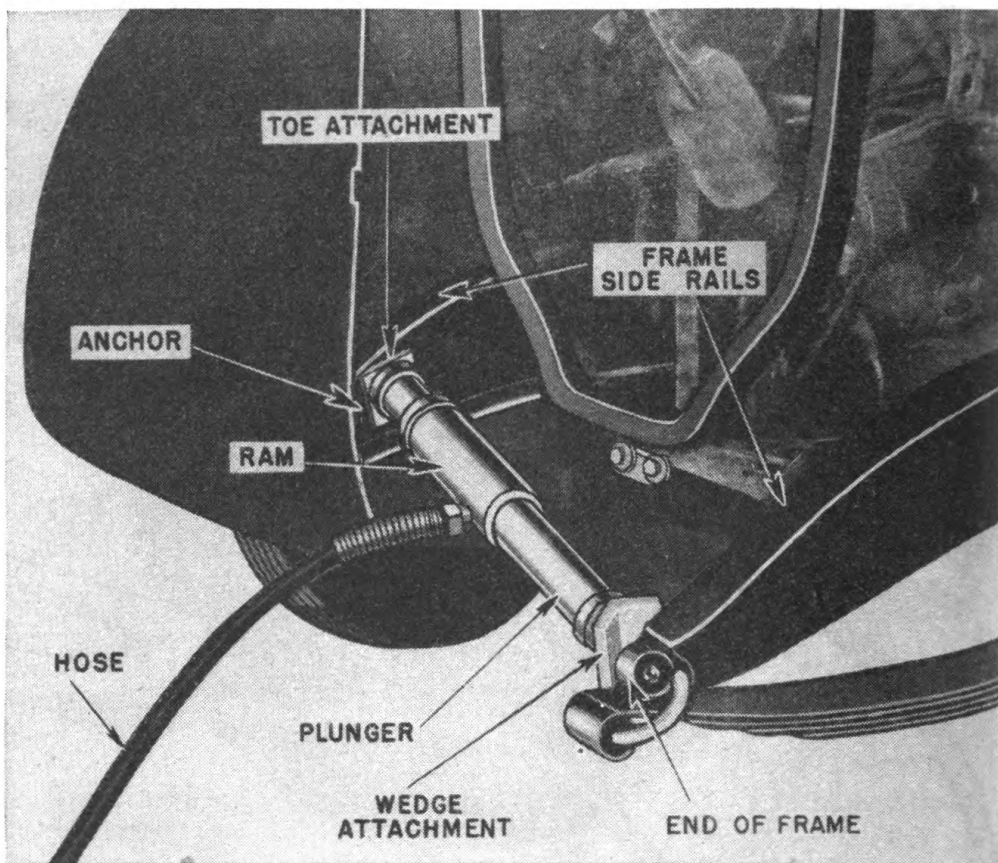


FIGURE 58.—Straightening front frame horn.

may be forced out by an angular push, as in figure 61, or pushed down by pressure at the opposite diagonal, as in figure 62. Figure 63 demonstrates how a dent in the upper quarter panel may be pushed out with the rubber head protecting the finish of the roof and the offset wedge securely anchoring the lower end of the ram.

(e) Using spreader toes (fig. 64), the hydraulic jack can force out tightly jammed panels. A toe may also be used with the rubber head to form a clamp, as in figure 65, which pushes the floor down to the frame.

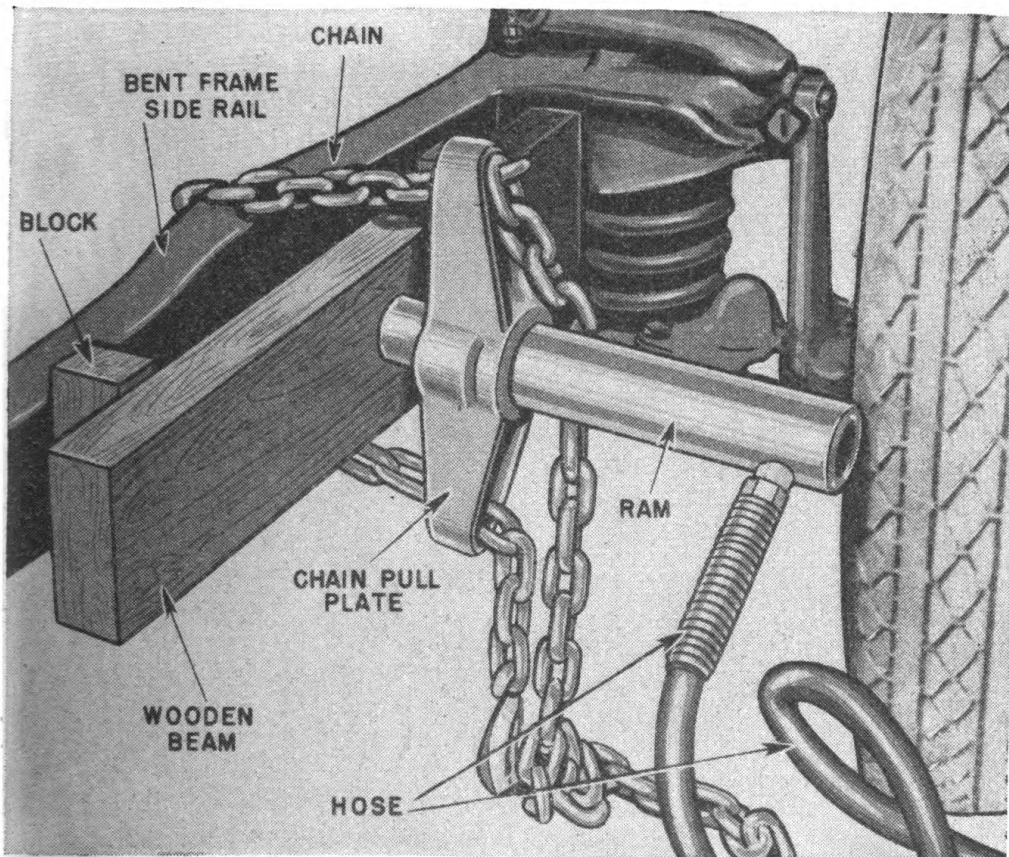


FIGURE 59.—Straightening bent frame channels.

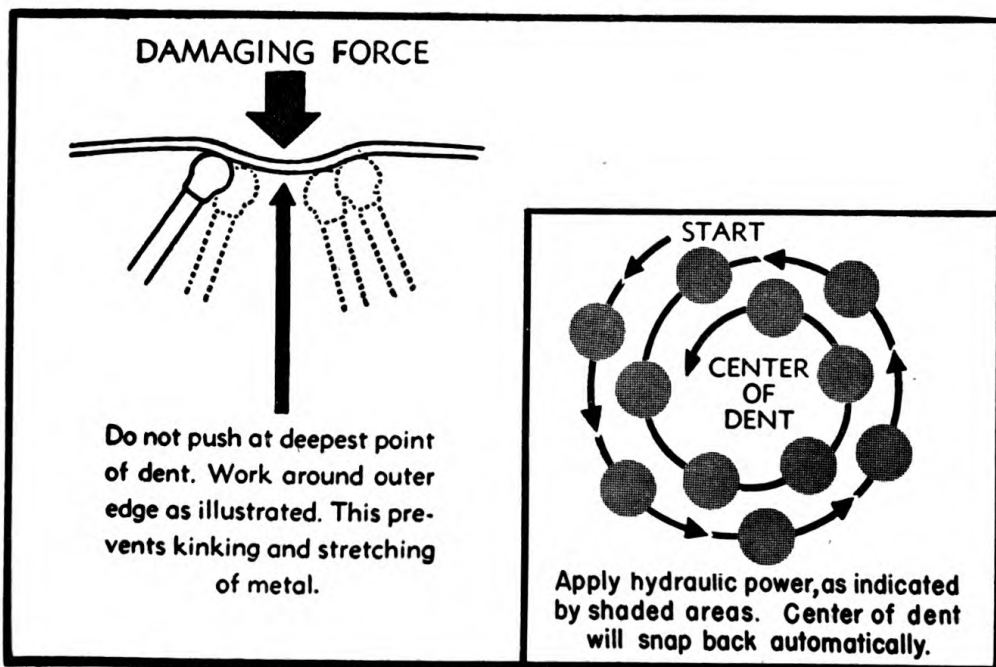


FIGURE 60.—Pushing body dent out.

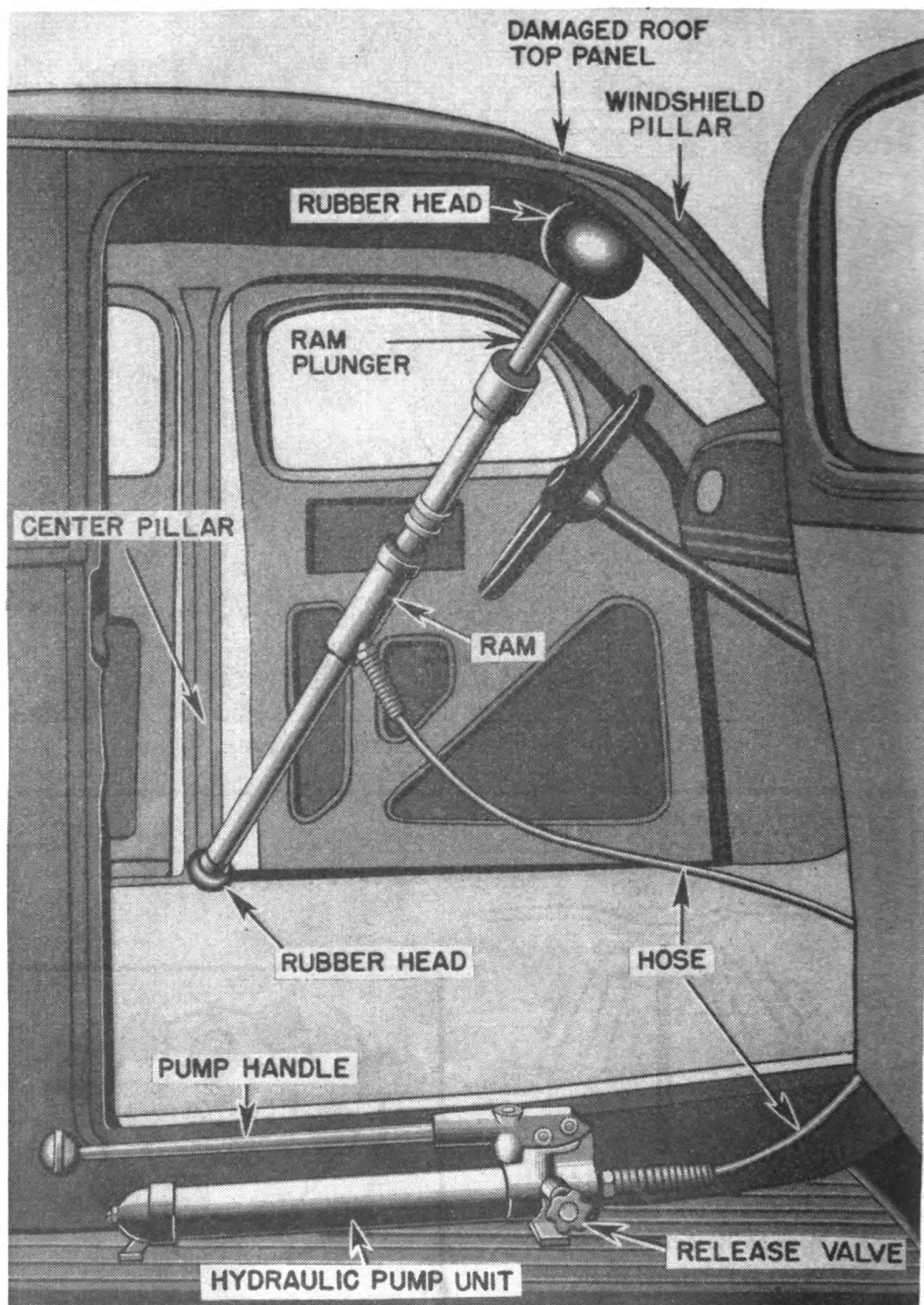


FIGURE 61.—Forcing door frame out.

(2) A small hydraulic wedge (fig. 66) may be slipped through a handhole to work in cramped quarters, as between panels of a door, back of instrument panels, or around roof rails, cowls, fender walls, body panels, and trunk compartments. It saves wrists from being slashed on saw-tooth edges of panels and enables removal of dents otherwise inaccessible.

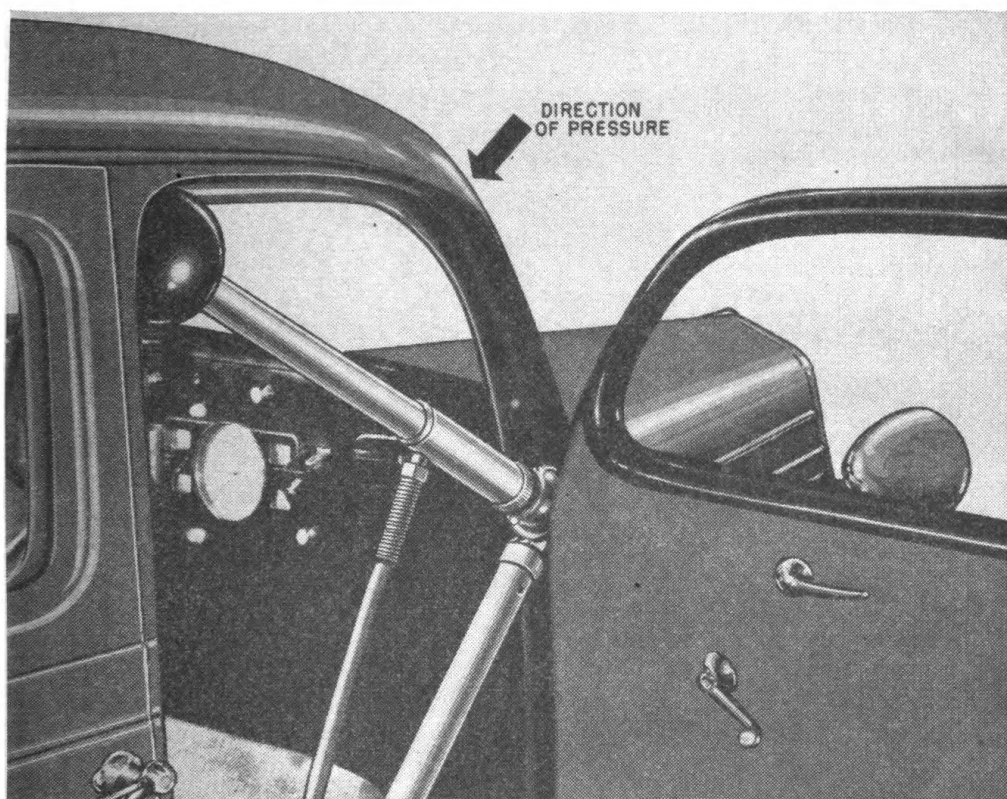


FIGURE 62.—Pushing door frame down.

(3) Use a door bar with clamps to increase or decrease the curvature of a door or header panel. In figure 67, wrench pressure at the support clamp corrects the contour of the door frame from top to bottom. In figure 68, the door bar is reversed so that pressure can be applied to reduce the curve of the door. In either set-up, the correction can be made from top, bottom, or center.

(4) Figure 69 shows the same door bar clamped at the windshield pillars with the center clamp exerting pressure at the center of the header panel. This alinement removes upward creases or dents in front of the steel roof.

24. Metal finishing.—Metal finishing, the third phase of body and fender repair work, is the process of smoothing a metal-bumped

dent to an even "plate glass" surface. Well done, it gives a good final appearance to a poor job of metal bumping; badly done, it leaves even the best metal-bumping job looking shoddy. Good metal bumping combined with good metal finishing yields a surface as good as new. After metal bumping, the surface of a panel or fender has slight irregularities such as small low spots, waves, and ridges. These are located by feeling the surface of the metal with the hand and by pushing a file across the surface to show up the low spots.

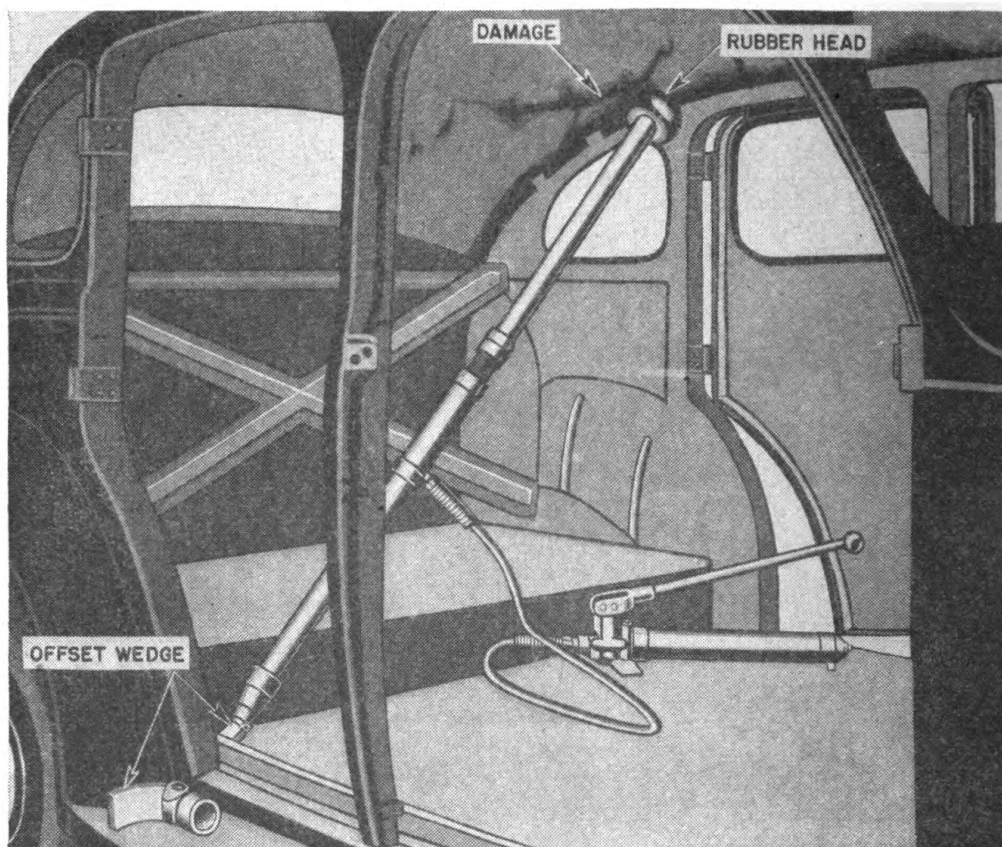


FIGURE 63.—Use of offset wedge.

a. Locating irregularities by hand.—(1) It is best to wear cotton gloves while metal finishing, not only to protect the hands, but to locate the irregularities more successfully. If slightly high or low spots are overlooked in the metal-finishing operation, they will show after the metal is painted, unless the painter feels them through the emery paper while wet-sanding the surface and has them corrected.

(2) Lay the left hand flat on the metal with the wrist somewhat relaxed, and drop the elbow until the wrist joint is only slightly

bent. The angle formed by the forearm and the hand is thus almost straight, as in figure 70. Rub lengthwise back and forth all the way across the damaged area. Keep the entire hand (heel, palm, and fingers) in full contact with the metal; the fingers alone are not sensitive enough to feel irregularities which the full hand easily locates.

(3) As experience is gained in body repair, the repairman will become so expert that he can feel very slight low spots with the hand, which the eye could normally see only when the job was painted and polished.

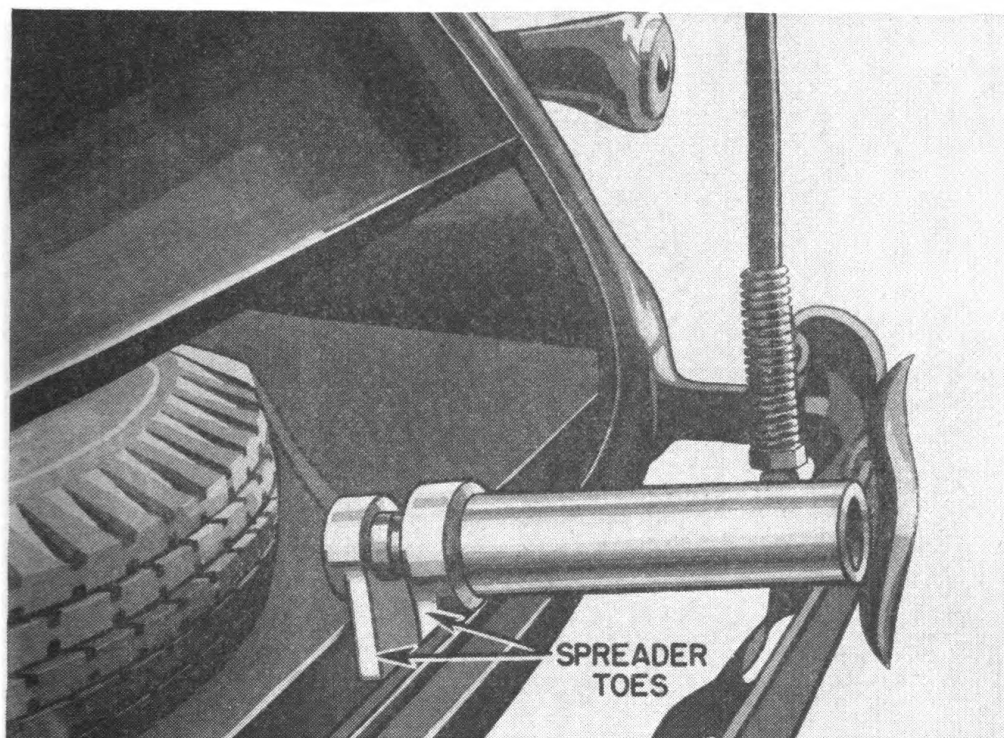


FIGURE 64.—Use of spreader toes.

b. Filing.—The Vixen file (fig. 71), widely used in metal finishing, is really a flexible metal file bolted to an adjustable holder. Its shape may be changed by an adjustment screw to fit the contour of the part to be filed. Turn the file about 30° crosswise to its line of travel (fig. 71) and, following the contour of the panel, take long, straight, regular strokes with a combined arm, shoulder, and body motion. The file may touch the metal on the return stroke without harm, but short, choppy strokes in either direction chew up the surface of the metal. It is not good practice to push the file straight down its length, except when filing beads and moldings. Take care

not to file too much metal, for the thin body and fender steel is easily punctured. At this stage, therefore, remove only enough to highlight wrinkles and waves; do not try to smooth the metal.

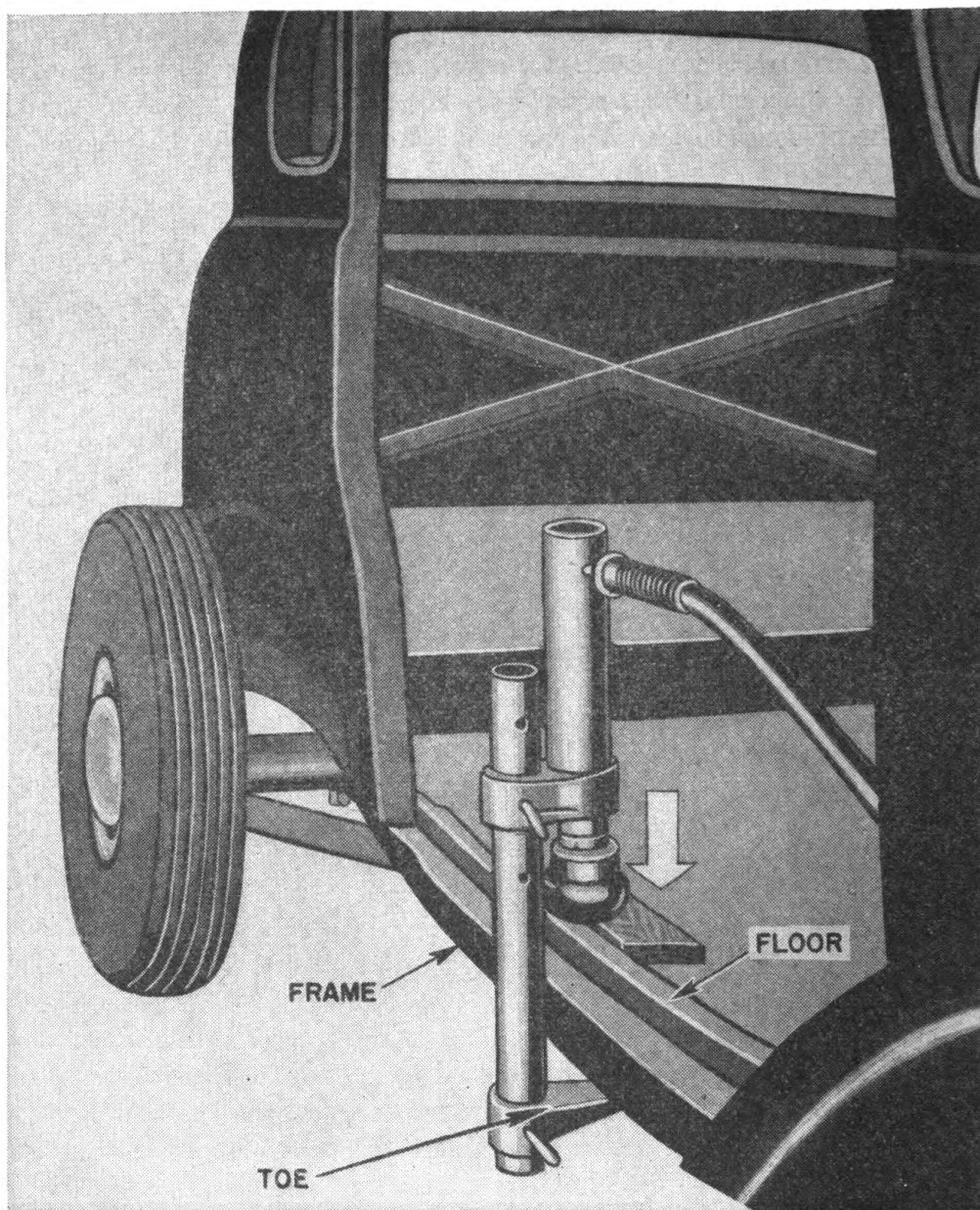


FIGURE 65.—Clamping floor into line.

c. Pick hammering.—(1) Low spots revealed by filing can be driven up with a pick hammer as illustrated in figure 72. A pick hammer raises not only the low point, but also an area of metal around the point, small if the pick is sharp, and larger if the pick is blunt. A

sharp pick hammer, therefore, should generally be used for small spots, and a blunt hammer for the larger spots. On high-crown panels, however, such as the nose crown of a front fender, a blunt hammer will raise the metal more smoothly; whereas on low-crown panels, such as the skirt of a front fender, the sharper pick end is best. As a rule, a wide, flat dent or an extra high-crown fender should be leveled by bumping it up with a dolly block rather than a pick hammer.

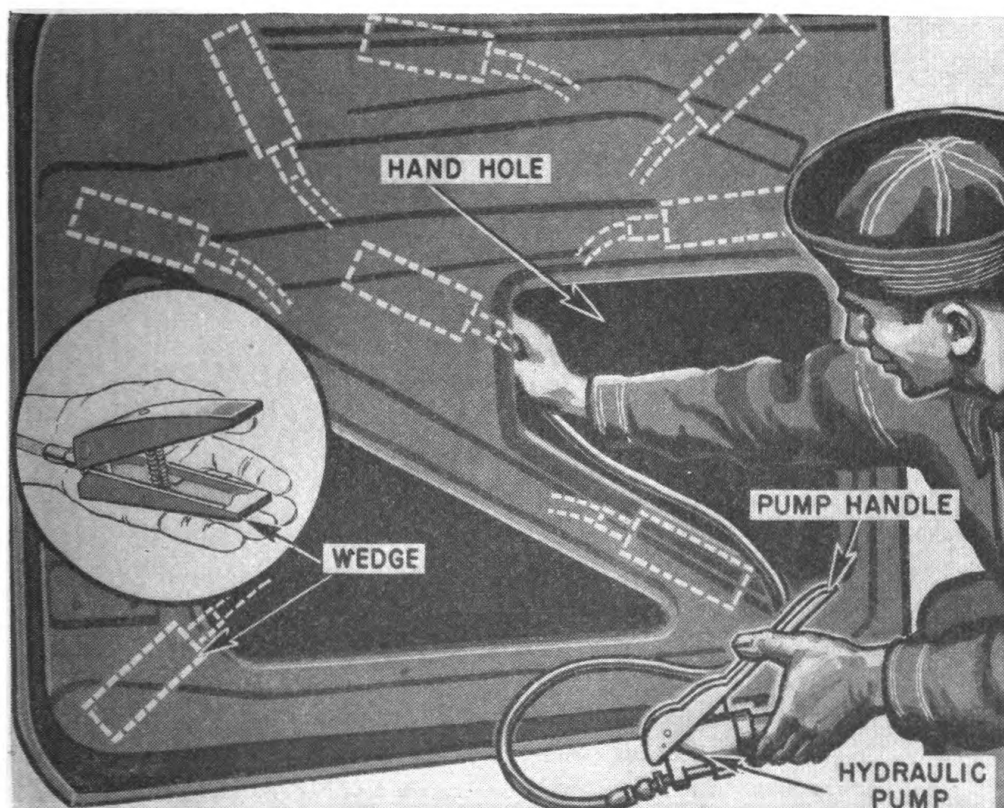


FIGURE 66.—Use of hydraulic wedge.

(2) An air hammer (fig. 73) makes metal finishing easier on an extra-high-crown panel, such as the nose crown of a front fender, which it can reach more easily than hand tools. This implement combines a hammering piston and a dolly block into one mechanism operated by compressed air. The dolly block, which rests on the dolly collar when the air pressure is off, is held against the under side of the metal until the piston stroke forces it to bounce momentarily away like a hand-held dolly. Before using it, clean the inside of the fender and coat both the inside and outside surfaces lightly with thin motor oil. Then set the air hammer in position and operate it, mov-

ing the piston and dolly mechanism slowly back and forth in overlapping lines of travel to insure a neat and thorough job.

d. Cross filing.—Even after a careful job of pick hammering, some unevenness remains. This is removed with a Vixen file. Manipulate it as in the first filing (fig. 71) but continue until no roughness is left except file marks or scratches.

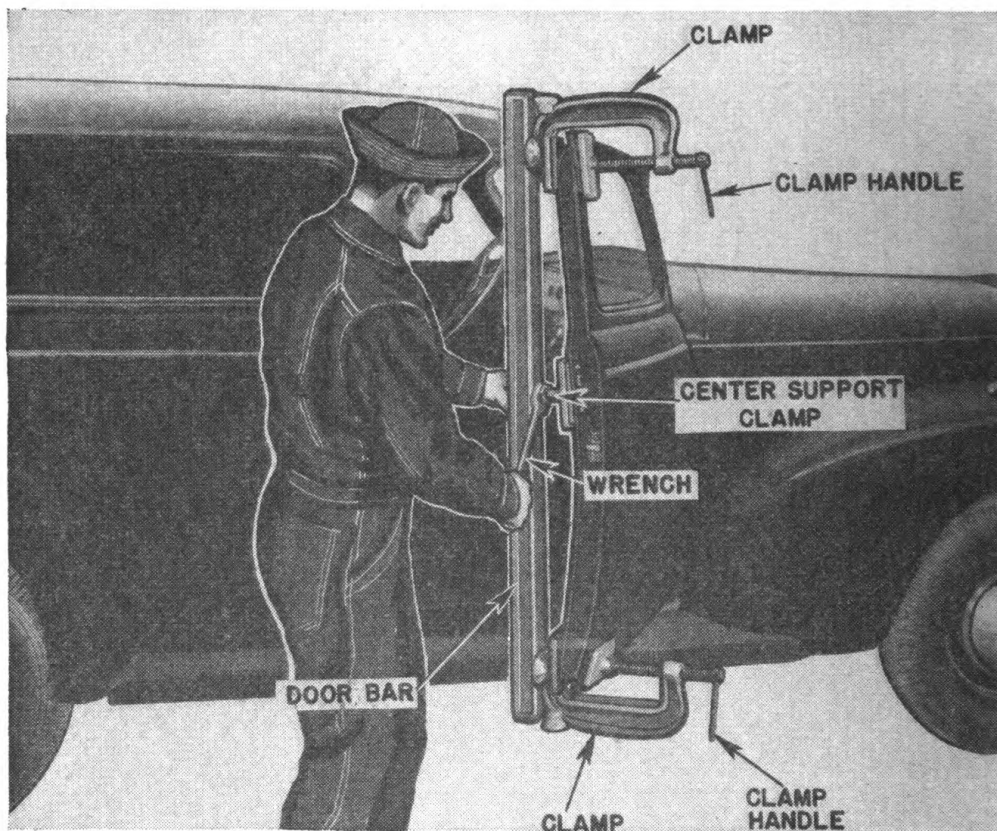


FIGURE 67.—Increasing door curvature with door bar and clamps.

e. Disk sanding.—The portable disk sander (fig. 74) removes marks or scratches left by filing. Abrasive disks, which are interchangeable, consist of abrasive grains bonded to a backing. The grains are carefully graded by size, measured as grit number. In open-coat disks the particles are spread apart to avoid glazing with old paint or solder. Close-coat disks, for sanding metal welds and harder materials, have a more compact coating.

(1) A No. 24 grit (open-coat) disk is recommended for paint removal, but it will wear rapidly if used for grinding or sanding steel.

(2) A No. 50 grit (close-coat) disk is used to sand scratches or burs after filing. Followed by two coats of paint, it yields a "plate glass" finish.

(3) A No. 36 grit (close-coat) disk is coarse enough to cut and yet fine enough not to gouge or scratch deeply. It also easily removes the No. 24 open-coat sanding marks. Any marks or scratches left by a No. 36 grit can be sanded away easily with the No. 50 disk. It takes considerable time to remove No. 24 or No. 16 grit scratches with a No. 50.

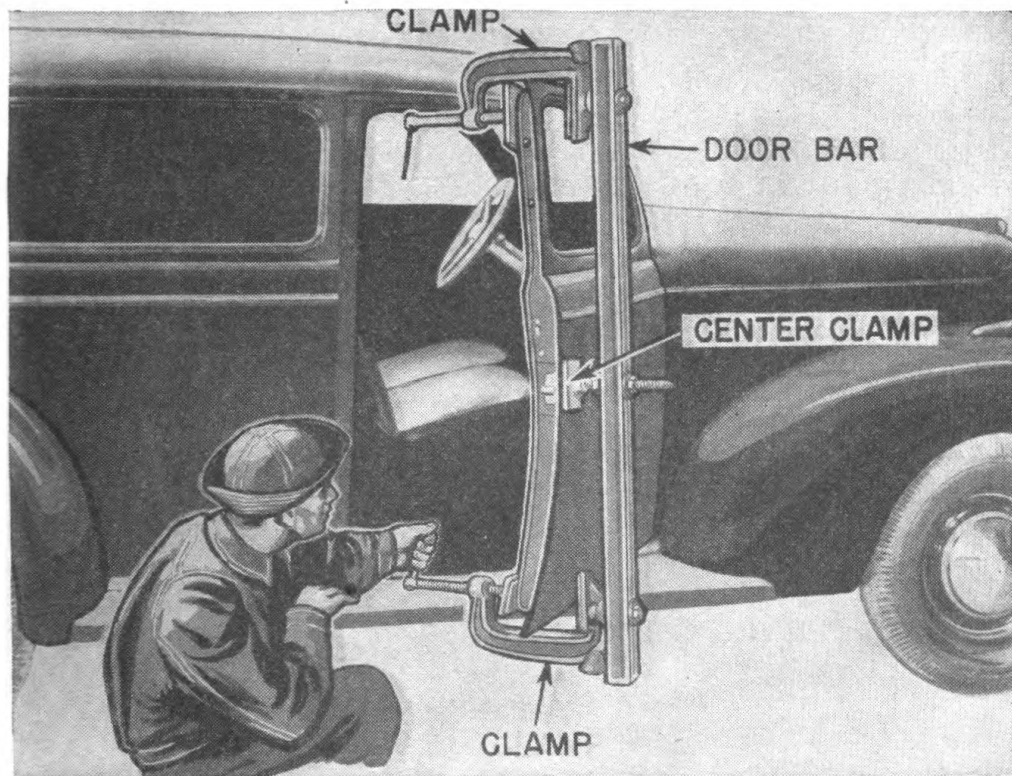


FIGURE 68.—Decreasing door curvature with door bar and clamps.

(4) When removing paint or scratches, a sander should take vertical, parallel, slightly overlapping strokes (fig. 74). As a cutting tool, it travels horizontally in overlapping lines. To cut efficiently, move the sander alternately from left to right and right to left as slowly as possible without burning the metal, meanwhile bearing down slightly, so that the alternate cutting angles will resemble those shown in figure 75.

(5) One practice in particular to be avoided is tilting the sander at a sharp angle to the work, so that only about $\frac{1}{4}$ to $\frac{1}{2}$ inch of the disk edge is used, gouging the metal. For better and faster results

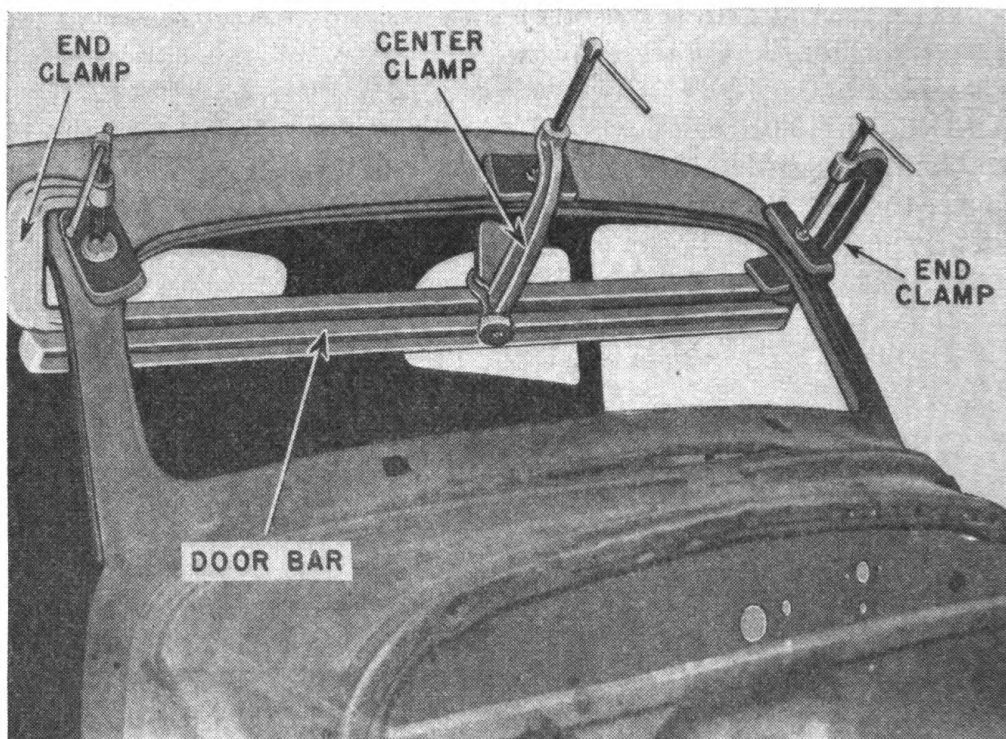


FIGURE 69.—Pulling header panel down with door bar and clamps.

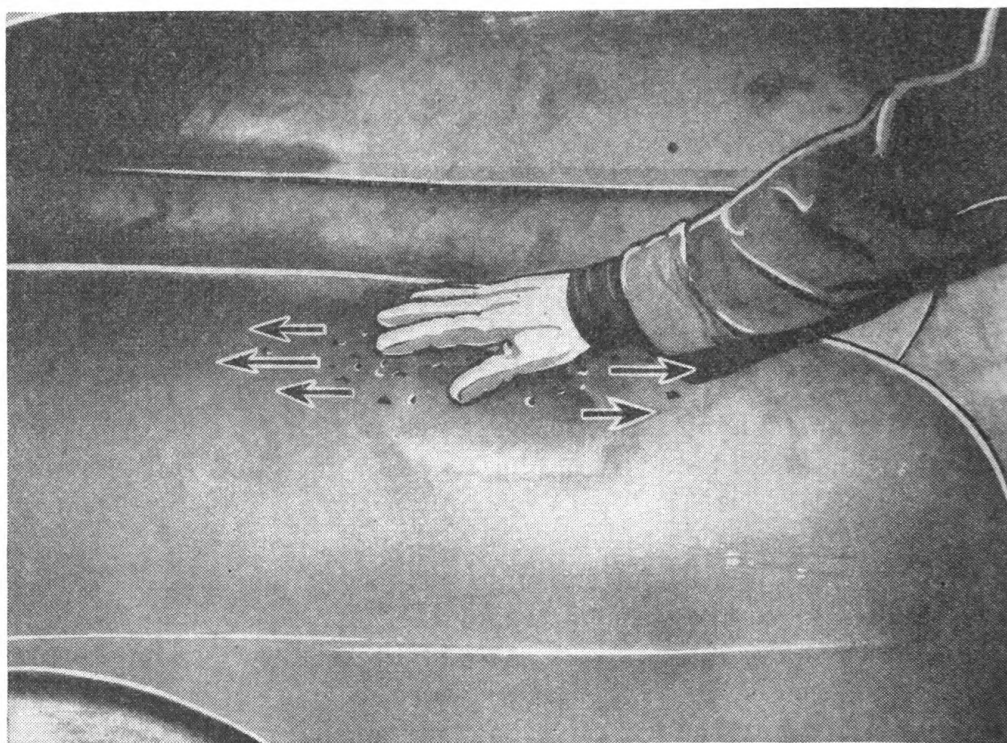


FIGURE 70.—Locating irregularities by hand.

and longer disk life, hold the disk as nearly flat as possible using at least 1 inch of the edge and preferably 2. When sanding along the edge of a panel, always run the disk off the edge. Start the sander off the job and stop it on the job. Do not lay it on the floor

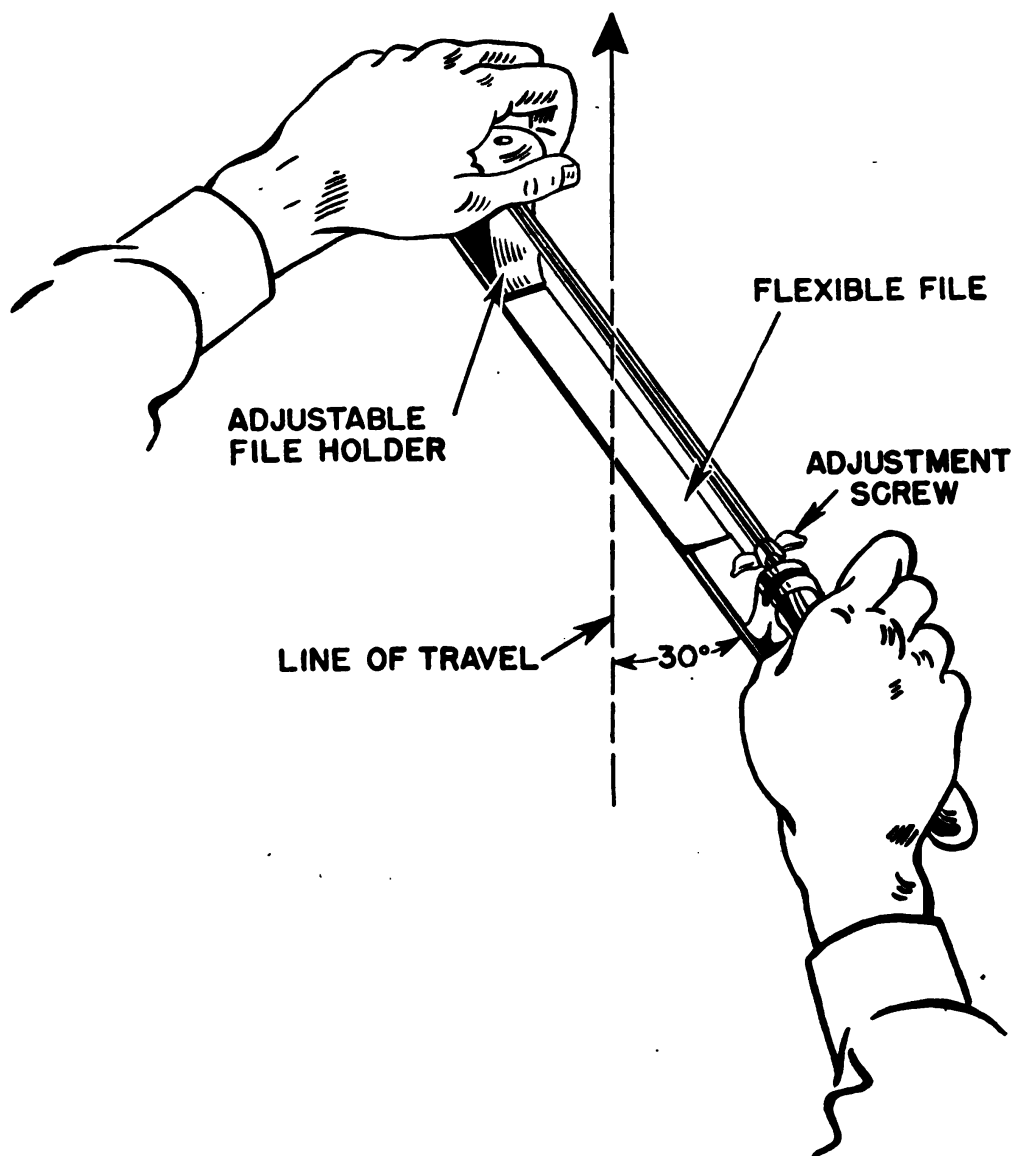


FIGURE 71.—Bushings a Vixen file.

with the motor running; the cooling fan will pull dust and dirt into the motor. Enough dust gets into the motor even in normal use. Clean the sander occasionally by blowing compressed *filtered* air through the cool-air intake while the motor is running.

25. Body and fender welding.—*a. General.*—(1) Body and fender welding is similar in principle to sheet metal welding discussed in paragraph 13. An oxyacetylene welding outfit, like that in figure 20, is a practical necessity in all shops doing body and fender repairing. It can be used for welding, brazing, cutting, heating, shrinking, and torch soldering. A soft iron welding rod, $\frac{1}{16}$ inch in diameter, a No. 1 torch tip, and a small neutral flame are best for body and fender metal. Larger shops offering complete

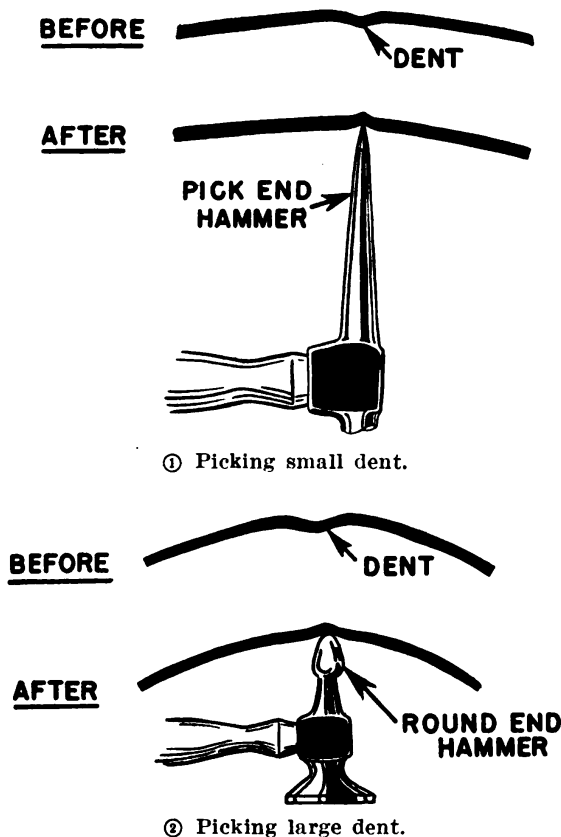


FIGURE 72.—Removing dents with pick hammer.

welding service including frames, new body panels, and light-gage metal reinforcements and braces will find enough use to justify a portable arc welder (transformer type).

(2) It is not practicable to braze a fender or any other panel subject to road shock. The braze only adheres to the steel instead of fusing like a weld and therefore lets go under vibration. In such case rebraze it or cut out the entire brazed area and weld a patch in its place for sheet metal cannot be welded until all the bronze is removed. If there is no danger of vibration, however, and the metal cannot be

safely heated to welding temperature, a braze may be better than solder.

b. Fender welding.—When welding a break or tear in a fender, first metal bump the fender and aline it to remove all strain from the torn area. Then, holding the split or torn edges together with clamps or pliers, tack weld the break at 1-inch intervals from its start along its entire length as shown in the sketch of figure 76. This will prevent

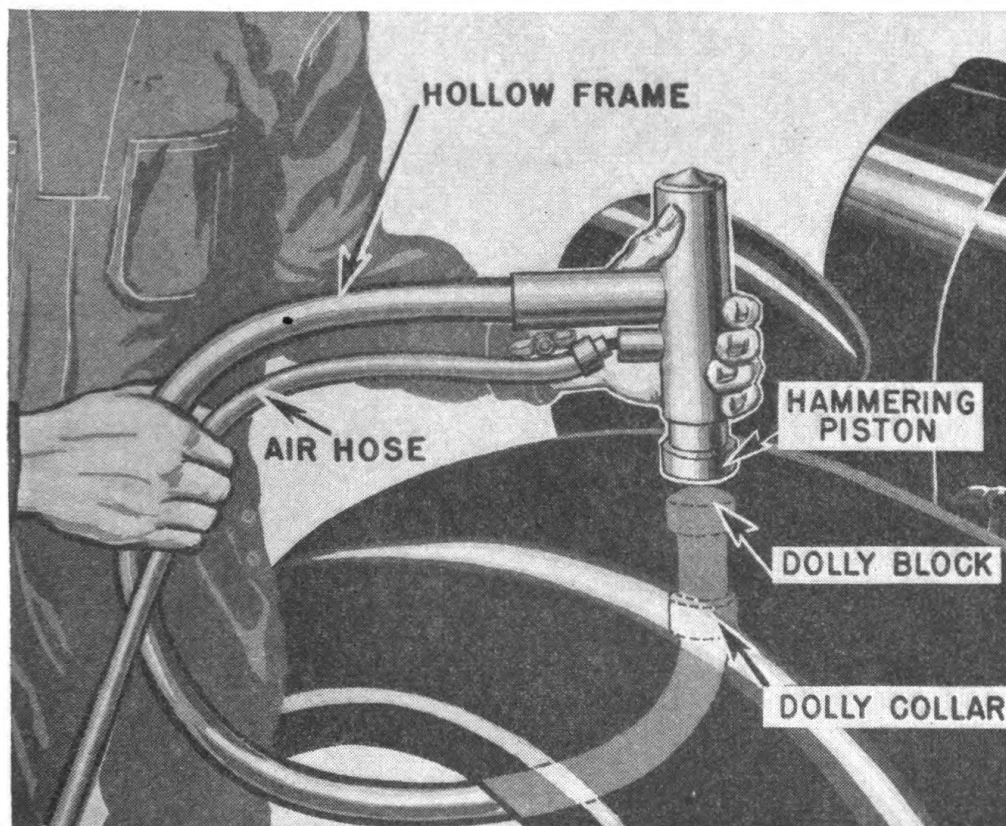


FIGURE 73.—Air-hammering front fender.

the welding heat from spreading and distorting the broken edges. Removing the pliers, complete the weld from the inner end of the break to the last tack weld, near the start of the break (fig. 77). Do not weld all the way to the flange of the fender (start of break) because the welding heat will melt the flange and leave a semicircular hole at this spot (fig. 78). The weakened flange which normally should strengthen and hold the side of the fender in shape would then sooner or later break and fail in its purpose. To avoid this, always begin welding a flange at the outside edge of the fender with about $\frac{3}{8}$ inch of welding rod (fig. 79), extending beyond the edge of the break. The broken edges and the extending end of the rod are thus brought to

welding heat at the same time, so that the molten rod flows back and fills the semicircular opening which would otherwise be left. This makes a full-width, strong flange as shown in figure 80. It is not necessary to reinforce the flange further by welding a piece of wire inside it.

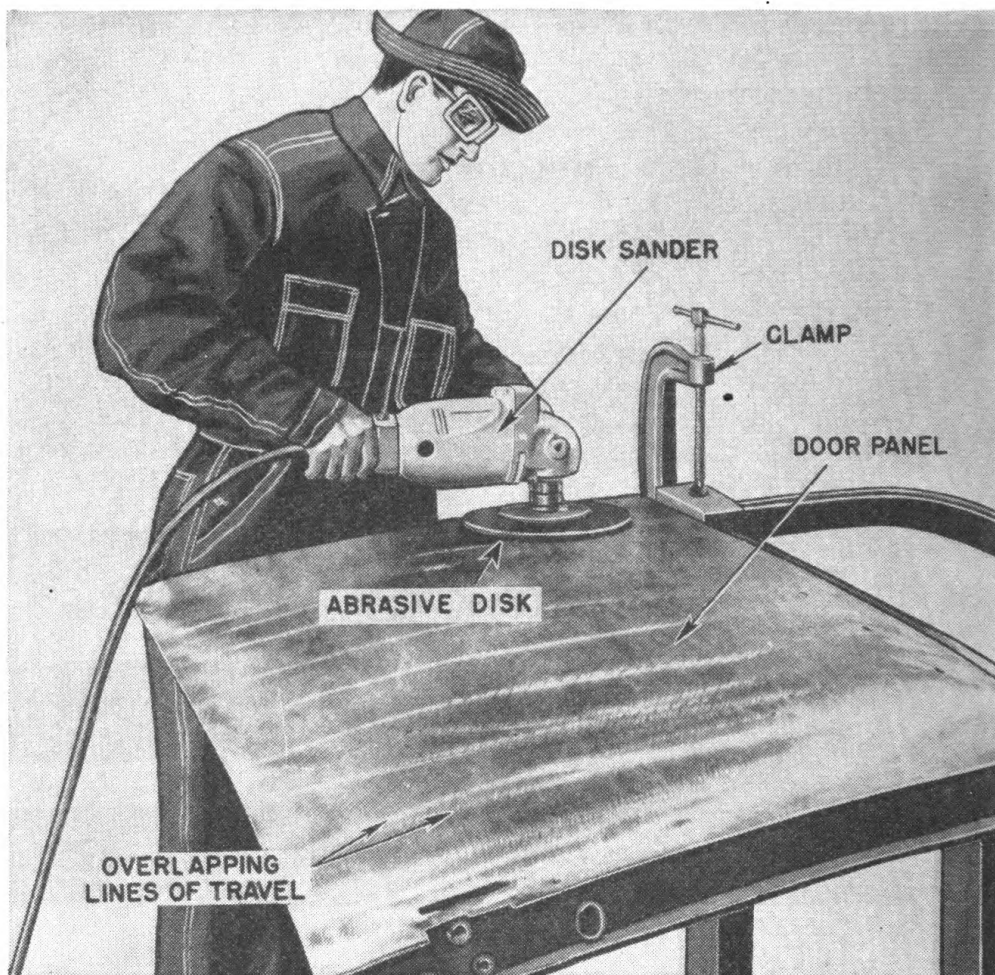


FIGURE 74.—Using disk sander.

c. Body welding.—Body metal should be welded forward (ahead of the torch tip) rather than backward, to avoid burning the weld or distorting the panel. Forward welding is rapid because the torch throws the heat ahead and preheats the metal about to be welded.

d. Forging a weld (fig. 81).—This will reduce the necessary metal finishing and produce a stronger weld. A weld in the center of a fender can be forged while it is still red hot. Weld about $\frac{1}{2}$ inch at a time, then quickly drop the welding rod and hammer the weld level and smooth, using a dolly underneath the weld as an anvil.

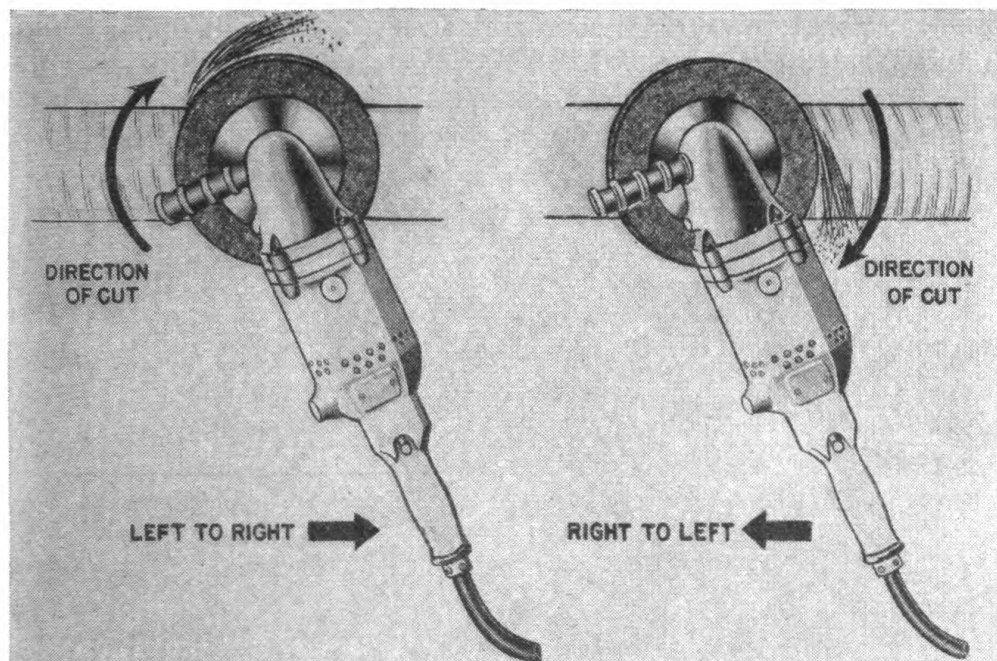


FIGURE 75.—Cutting stroke of disk sander.

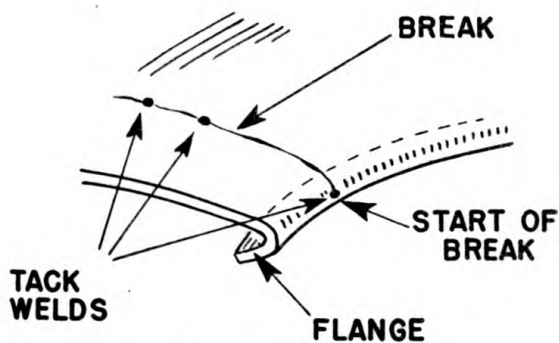


FIGURE 76.—Tack welding.

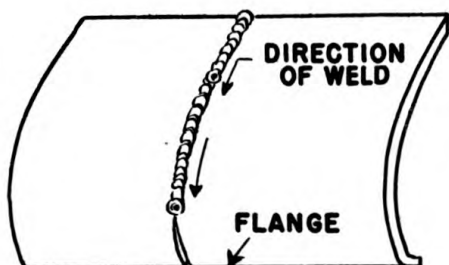


FIGURE 77.—Direction of fender weld.

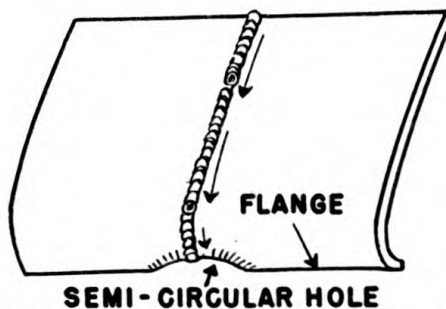


FIGURE 78.—Result of welding to flange.

Repeat this procedure until the full length of the break is welded and forged. Forging a weld leaves a relatively smooth finish and is a fast and cheap procedure.

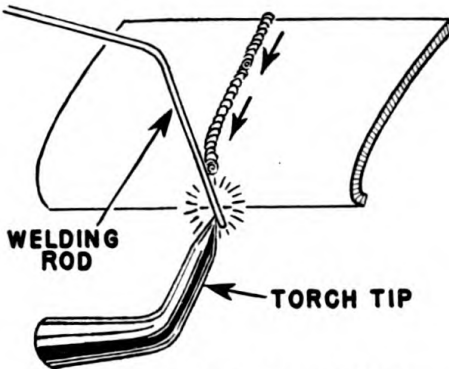


FIGURE 79.—Welding flange correctly.

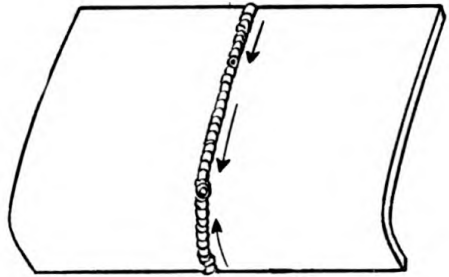


FIGURE 80.—Completed weld.



FIGURE 81.—Forging a weld.

26. Metal shrinking.—When a panel has been stretched by damage, the metal must be shrunk. This is done by heating a small spot in the center of the stretched area and then upsetting (hammering

down) the stretched metal into this heated spot. A center heat (1, fig. 82) hammered down, followed by successive rim heats similarly hammered down, constitutes the complete shrinking operation. For a long, narrow stretch, shrink a spot at each end and then shrink the center portion.

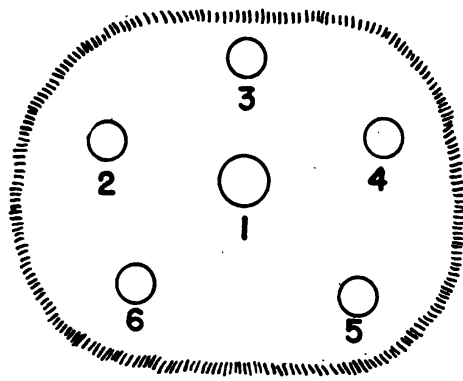


FIGURE 82.—Sequence of heats in metal shrinking.

a. Preparation for shrinking.—The habit of having tools and equipment conveniently arranged in advance will greatly facilitate metal shrinking. Begin by metal bumping the entire dented area, including the stretched surface, to indicate the exact size and nature of the bulge or stretch as shown in figure 83. Then remove the paint with a scraper or with a torch and a wire brush. The scraper avoids the hazard of ruining eyesight from the glare of burning paint.

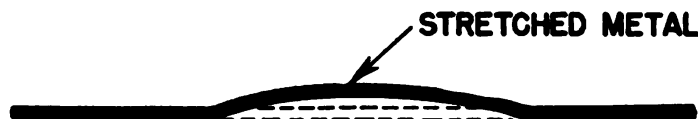


FIGURE 83.—Metal to be shrunk.

b. Metal shrinking a panel.—The procedure is as follows:

(1) With a small-tipped oxyacetylene torch (see TM 10-440) heat a small spot in the center of the stretched area to cherry red (fig. 84). As the heat expands the metal in the entire stretched area, the red spot rises in a peak as in the sketch of figure 84. Take care not to burn a hole in the metal. The size of the heated spot will naturally vary according to the work, but it is well to remember that body metal loses its temper or spring when heated to a cherry red. Therefore, heat spots small enough that most of the metal retains its natural resiliency. In general, on a normally curved surface, a heated spot should not exceed $\frac{1}{8}$ inch in diameter although as much as $\frac{3}{16}$ of an inch would be permissible if the curvature was slight. On flat sur-

faces, heated spots as large as a nickel are suitable. *Under no circumstances, however, should larger spots be heated.*

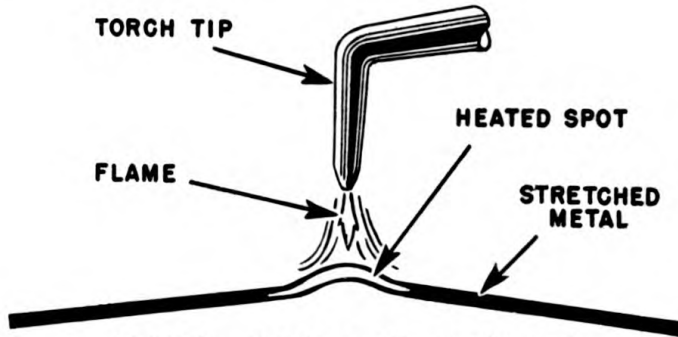


FIGURE 84.—Heating small spot with torch.

(2) Then, as quickly as possible, lay the torch down and strike a hard blow with a flat-faced dinging hammer or mallet directly on the heated spot, driving it down. Use a backing-up tool such as a dolly. The hammer blow upsets the hot metal and shrinks it, leaving the spot in the shape of a crater (fig. 85).

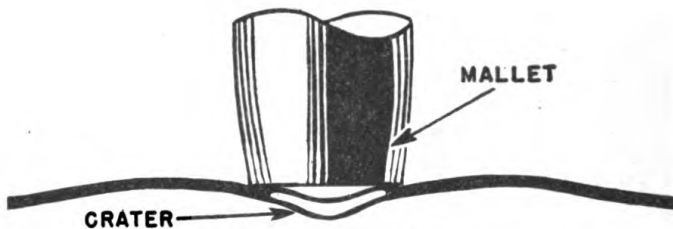


FIGURE 85.—Hammering the heated spot down.

In figure 85 note that the mallet face is much larger than the heated spot. That is important. A slow-motion picture would show the center of the mallet face first striking the peak of the heated spot, driving it down level with the cooler metal around it. Then the outer part of the mallet-face would strike the cooler metal, forcing the entire stretched area in toward the heated spot and making the heated metal thicker. This is why large spots are not satisfactory. If the mallet face does not overlap on the cooler metal around them, it cannot upset the cooler metal into the heated spot.

(a) Metal can be shrunk without using a dolly block at all—merely heating, upsetting, and quenching—but it is much better to ding the hot metal smooth, because the stretched metal is thus further upset. The surface is left at normal level for metal finishing.

(b) Beware of too many heated spots which will overshrink the metal, buckling and warping the panel. If this should happen, stretch the overshrunk area with a hammer and dolly.

(c) Sometimes a sharp, deep stretch resists rising in a peak when it is heated. This should be raised, hot, with a dolly (flat face for low-crown metal, low-crown face for high-crown metal), then dinged smooth and quenched.

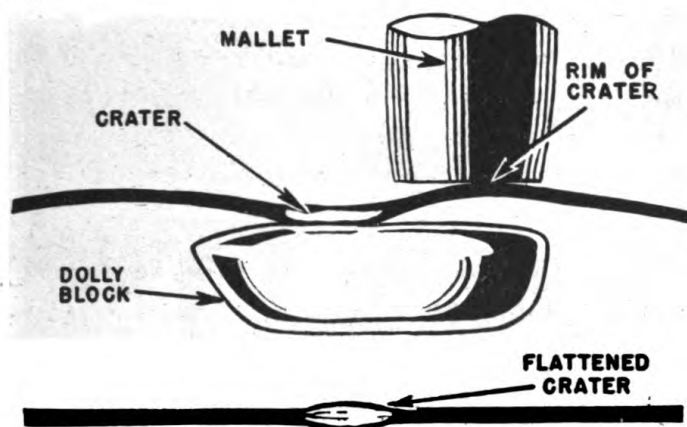


FIGURE 86.—Flattening the crater.

(3) Next, as quickly as possible, press a dolly block from the inside against the bottom of the crater and tap the rim of the crater from the outside with a dinging hammer or mallet (fig. 86 upper). Use a low-crown dolly block with low-crown metal and a high-crown dolly with high-crown metal. This smooths the crater for metal finishing (fig. 86 lower). Note that the metal is still somewhat expanded from the heat.



FIGURE 87.—Quenching shrinkage.

(4) Finally, with a wet sponge quench or chill an area about 6 inches in diameter all around the shrunk spot (fig. 87). This chills the heated metal and completes the shrinkage. Using additional up-sets, instead of quenching to complete the shrinkage, is a waste of time.

27. Paddle soldering.—Paddle soldering, sometimes called torch soldering, is simply applying an even surface of solder over welds, rough surfaces, and low spots. It becomes necessary when small dents cannot be reached in body panels without removing upholstery and other parts, or when the metal that has become too thin has to be built up to its original thickness and contour. For this purpose most

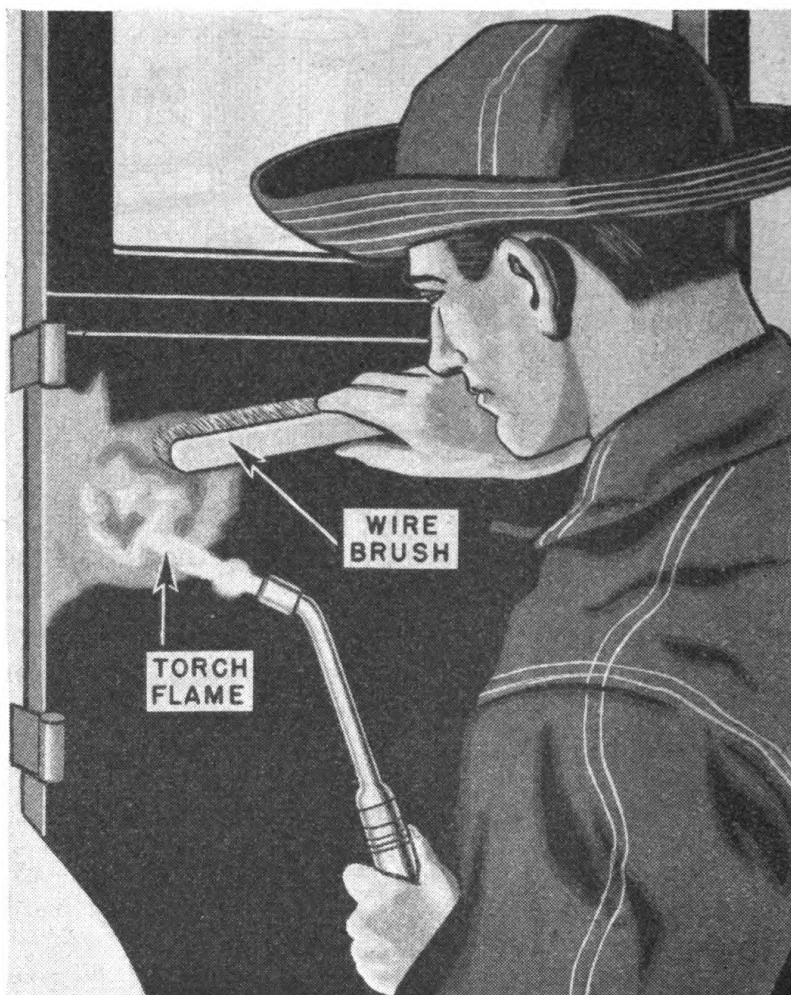


FIGURE 88.—Cleaning with torch and wire brush.

repair shops use a solder commonly known as body solder, which has a wide plastic range. If the solder is used to cover a break in the metal, other means must be provided to strengthen the joint. For example, the metal may be first welded and hammered, and then the rough surface filled with solder and filed smooth. *Never rely on solder for strength.* The general information on the composition and characteristics of solder, fluxes, and cleaning acids given in paragraph 9

is equally appropriate to paddle soldering. Remember that thoroughly clean metal surfaces, well-tinned, are the foundation of all good soldering.

a. Cleaning.—Before paddle soldering, remove all paint, grease, dirt, and rust from the surface of the dent by scraping, sanding, or filing. Rust and welding scale can be removed easily with a wire



FIGURE 89.—Applying flux with acid brush.

brush attached to a disk sander. Old paint, burned with a torch, can be brushed off easily while it is still hot, with a hand wire brush as shown in figure 88. Clean the surface about 2 inches beyond the rim of the dent to assure complete filling.

b. Applying flux.—Heat the cleaned area with the torch before applying flux with an acid brush or swab. This heat aids the flux in dissolving the oxides on the cleaned surface (fig. 89).

c. *Tinning.*—Again heat the metal just enough to take a deposit from a bar of solder (fig. 90) as it is rubbed against the dent. Using the torch intermittently keeps this deposit liquid as it is spread and wiped with a clean rag over the entire cleaned area.

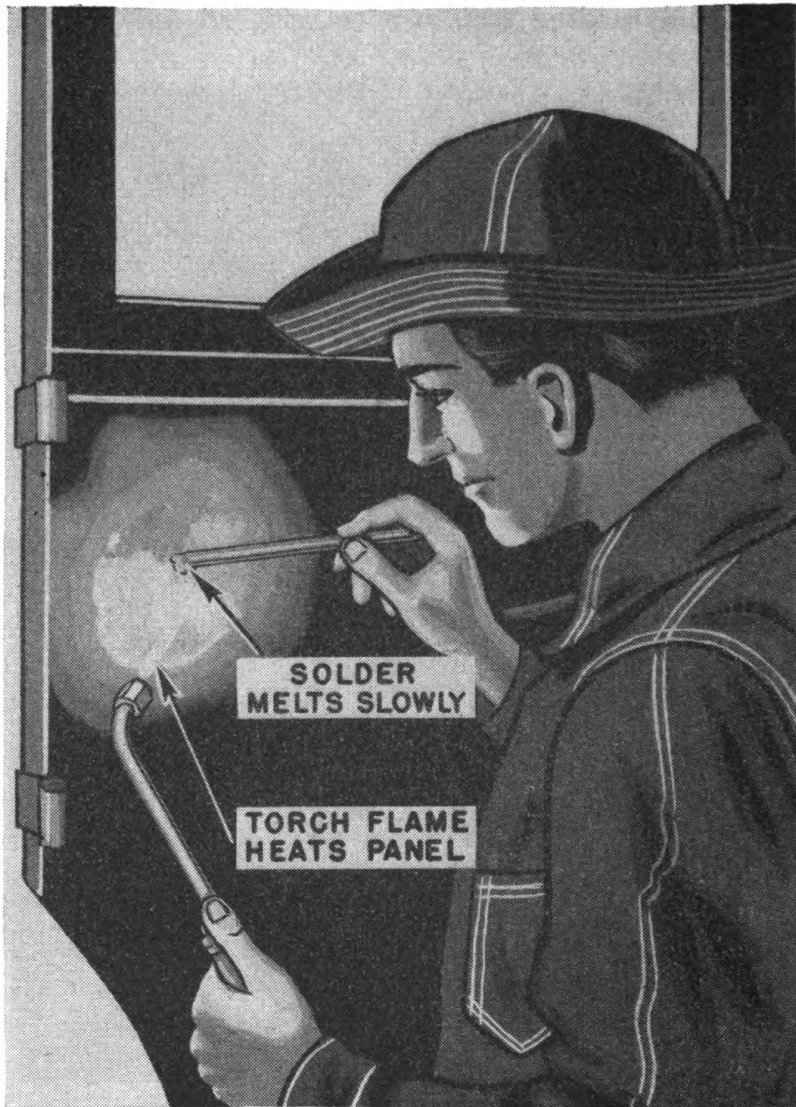


FIGURE 90.—Tinning.

d. *Filling dent.*—Hold the torch flame at the edge of the dent and parallel to it, occasionally brushing the tinned surface with the end of the flame to keep it warm enough to hold the solder as it is deposited. Hold a bar of solder at the end of the flame until about 1 inch of the bar becomes plastic and sags; then quickly press it against the warm tinned surface. Continue the process, occasionally brushing the flame

over the deposited solder to keep it in a plastic condition, until solder completely fills the dent (fig. 91). Never heat the solder to the melting point.

e. Shaping.—Smooth and shape the plastic solder with a maple paddle (fig. 92) greased with refined mutton tallow or light motor oil. As the solder cools, apply the torch flame briefly to keep the solder plastic while the smoothing continues until the desired shape is obtained.



FIGURE 91.—Filling dent with solder.

f. Precautions.—(1) Avoid overheating the solder so that it becomes molten and runs. Once the solder has been melted and then cooled, it permanently loses most of its plastic qualities, so that the filled area cannot be smoothed and shaped.

(2) A low-crown panel, such as a lower door panel or steel top panel, will buckle and warp from heat expansion while being soldered unless a large water-soaked sponge is pressed firmly on the heated area after the solder has cooled enough to become solid.

(3) Keep the solder clean. Dirty solder leaves pits which would later show up through the new paint. Grease from the refined motor oil can be easily "killed" or removed for painting with naphtha or any other solvent commonly used to clean a panel before painting.



FIGURE 92.—Shaping with paddle.

g. Metal finishing solder.—(1) A properly soldered job will require very little metal finishing, for solder that more than fills the dent is merely waste. It takes longer to put it on and longer to smooth it off. The soldered spot should be only slightly higher than the adjoining metal, just enough to allow even filing.

(2) Because solder is much softer than body steel and therefore cuts away faster, do not disk-sand it. A disk sander will cut into

the solder leaving it lower than the surrounding steel and showing it up as a "bull's-eye" after painting and polishing. It is best to file the edges of the filled area first and then finish the center, taking care not to cut the solder lower than its proper level. Use a Vixen file first, followed by an open-cut solder-float file, which cuts solder slowly, cleaning the slight ridges and file marks left by the Vixen file and leaving the surface in good shape for sanding with a No. 60 or No. 80 grit emery cloth. Sand the edges first, thoroughly rubbing the steel panel around the filled area, and then lightly finishing the solder. Take care to avoid sanding the solder down below the normal level of the panel.

SECTION V

RADIATOR REPAIR

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Radiator construction.....	29
Radiator cleaning.....	30
Testing radiator for leaks.....	31
Radiator failures.....	32
Removing and replacing overflow pipes.....	33
Repairing tanks and fittings.....	34
Repairing frozen cores.....	35
Major core repairs.....	36
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28. General.—The radiator of a motor vehicle is an essential element of the cooling system. It must function correctly if the engine is to escape serious damage from overheating. An engine is cooled by circulating water which passes through the cylinder block. It draws out the heat and then releases it to the air while flowing through the radiator. Therefore, if this circulation is hindered or the water leaks from the radiator, immediate repairs must be made to protect the engine.

29. Radiator construction.—Automobile, truck, and tractor radiators consist of two water tanks (upper and lower) joined by a core which does the actual cooling (see fig. 93). Water from the cylinder block usually enters the upper tank through the inlet, flows through the core, and leaves by the lower tank. A $\frac{3}{8}$ -inch overflow pipe in the upper tank (figs. 93, 94, and 95) carries away excess steam or water. In the radiator assembly shown in figure 93, cast-metal tanks are bolted to the side numbers. Gaskets between the tanks and core make a watertight connection. This type of rigid radiator construction is usually used on heavy-duty trucks and tractors. Figure 94 illustrates a sheel-type radiator formed by soldering

drawn or stamped metal tanks to the radiator core. The side members are straps of sheet steel soldered to the upper and lower tanks. This much lighter construction has generally replaced the cast metal

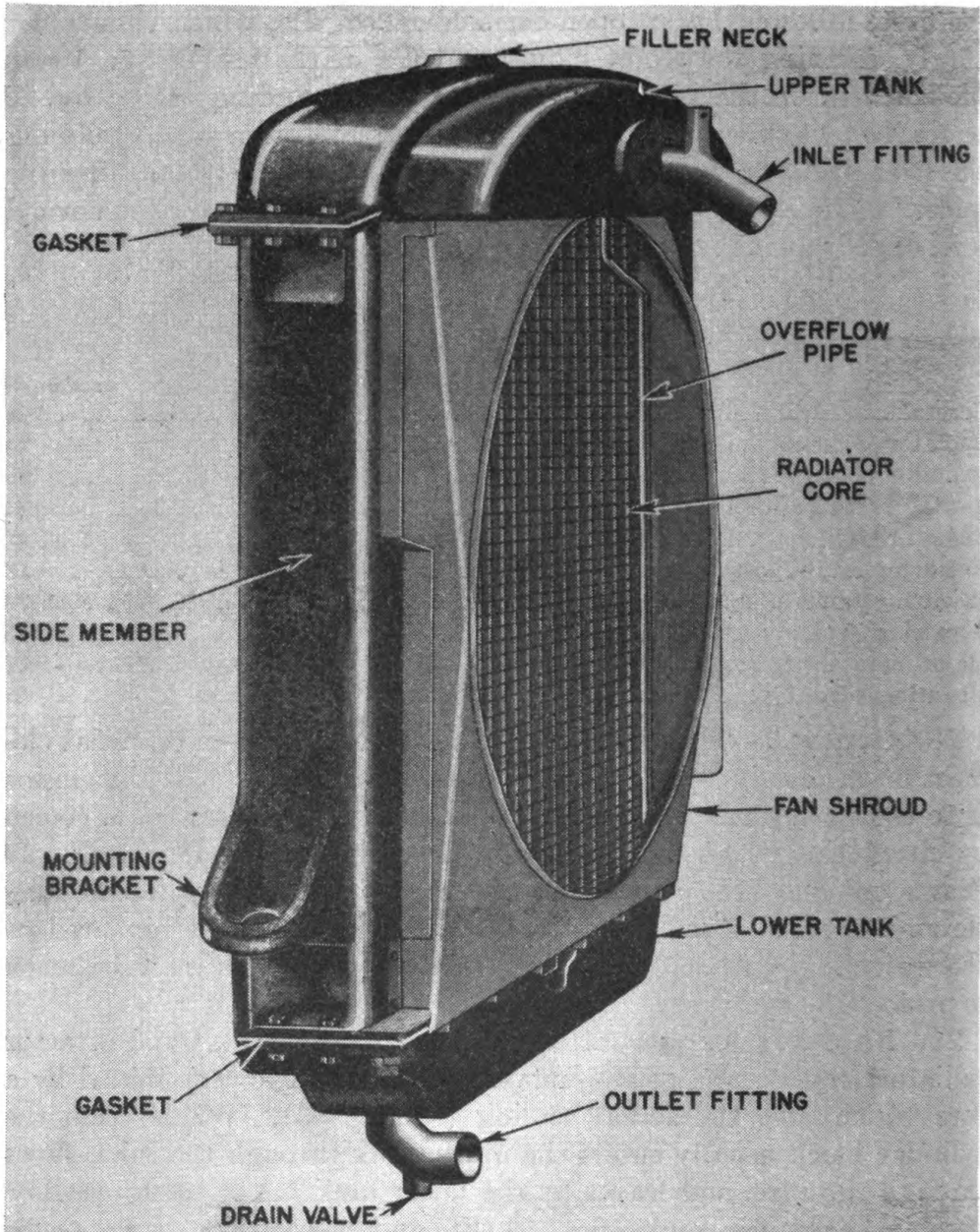


FIGURE 93.—Cast metal radiator.

type in passenger cars and light-duty trucks, where it is usually concealed by the hood and radiator grille.

a. Water tanks.—Almost all radiator tanks are cast or stamped in one piece to reduce the number of potential leaks. A baffle plate in

the upper tank, below the filler neck, eliminates excessive splashing and distributes the water uniformly over the tank. The cutaway view (fig. 95) illustrates the construction of a stamped metal tank.

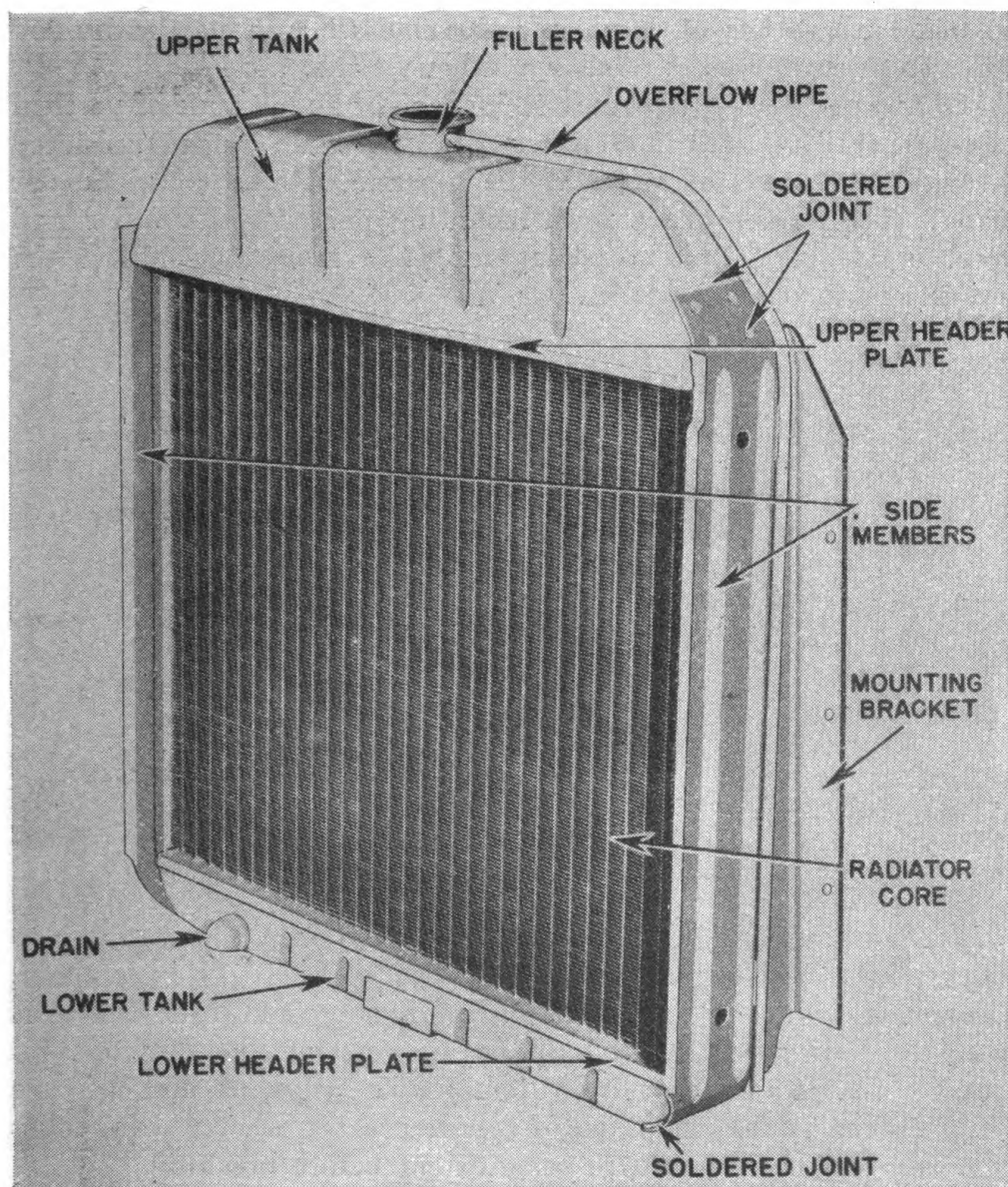


FIGURE 94.—Stamped metal radiator.

b. Cores.—Radiator cores are made with a large surface area of very thin sheet metal so that the heat of the water passing downward through the small passages may be readily transferred to the air. The water passages of the core are known as the “prime” radiating portion. The fins or filler constitute the “secondary” radiating por-

tion. Heat passes from the circulating water to the water passages and then to the fins where it is expelled to the passing air. The secondary radiation is as important for cooling as the primary radiation; be careful, therefore, not to damage the fins. Radiator cores are made in a variety of shapes and sizes, but all cores may be divided into two general classes: tubular and honeycomb.

(1) *Tubular core.*—(a) Figure 96 is made of a multitude of vertical tubes, generally $\frac{1}{4}$ inch in diameter (drawn or seam-welded) soldered through thin sheets of metal at the top and bottom, called header plates. The header plates form mounting pads for the upper and lower tanks and permit no passage of water from the tanks to the core except through the tubes.

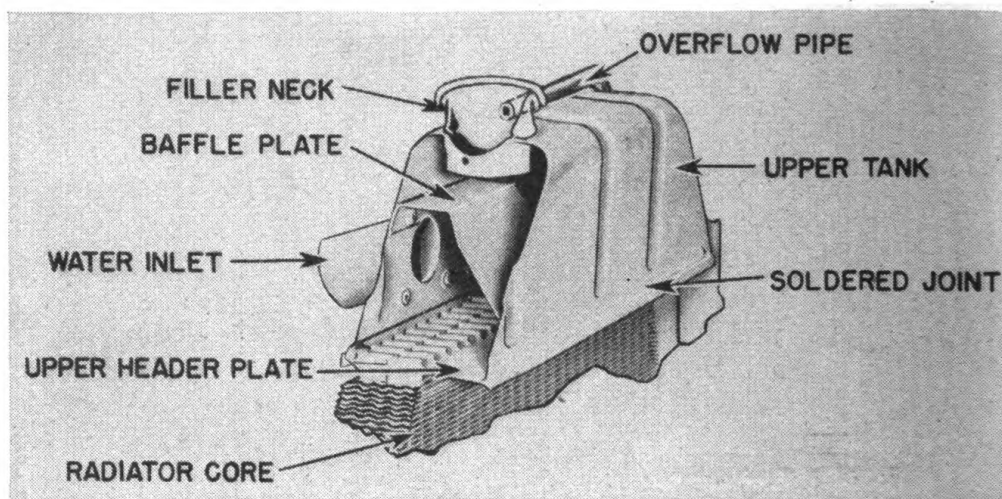


FIGURE 95.—Stamped metal radiator tank (cutaway).

(b) The tubes are generally spaced about $\frac{3}{4}$ inch apart, in two to four straight or staggered rows (figs. 97 and 98) $\frac{1}{2}$ inch apart, across the width of the radiator. In a staggered row, twice as many tube rows are exposed to the air entering the radiator, increasing the cooling capacity. Round tubes (figs. 97 and 98) are easily broken by the expansion of freezing water, whereas oval tubes (fig. 96) will be distorted to some extent before breaking.

(c) The radiating surface of these tubes is occasionally increased by spiral fins on each tube, or much more commonly, as in figures 93 to 98, by thin sheets of metal (horizontal fins) extending all the way across the radiator, $\frac{1}{8}$ to $\frac{3}{16}$ inch apart, in contact with each tube. The front edges of horizontal fins are usually crimped or bent back to a double thickness which strengthens the radiator core. In most radiator cores the fins are soldered to the tubes to speed the

heat transfer. A tubular core radiator is generally larger than a honeycomb core radiator with the same cooling capacity.

(2) *Honeycomb core*.—(a) One type, illustrated in figure 99, has slot-like water passages extending vertically through the core be-

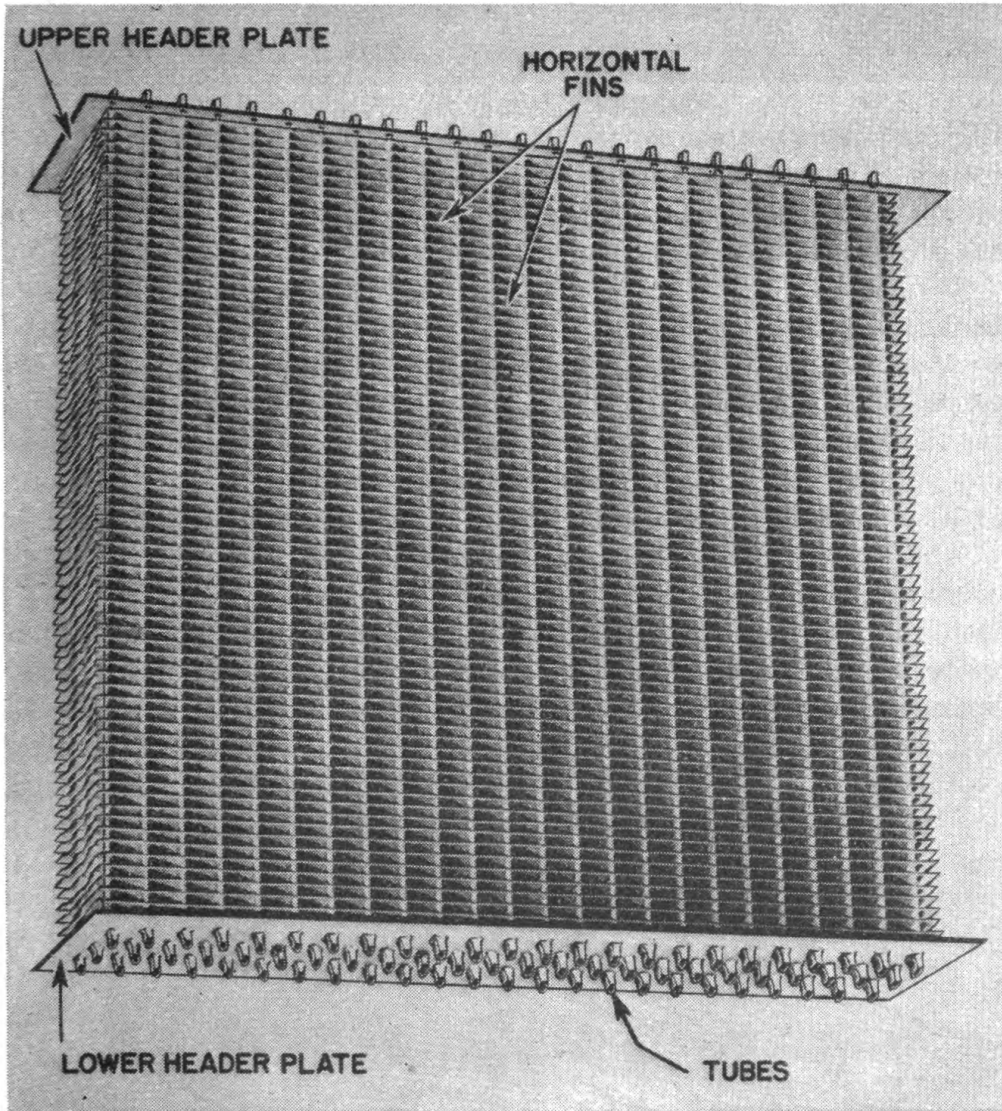


FIGURE 96.—Tubular core.

tween sections of honeycomb-like air cells. Each section has offset-stamped metal ribbon around the outside and bent fins within. Adjacent sections are soldered at the offsets, which are about $\frac{1}{4}$ inch wide and extend about $\frac{1}{4}$ inch in from each face of the core. The ribbon at the top of a section is called the header strip.

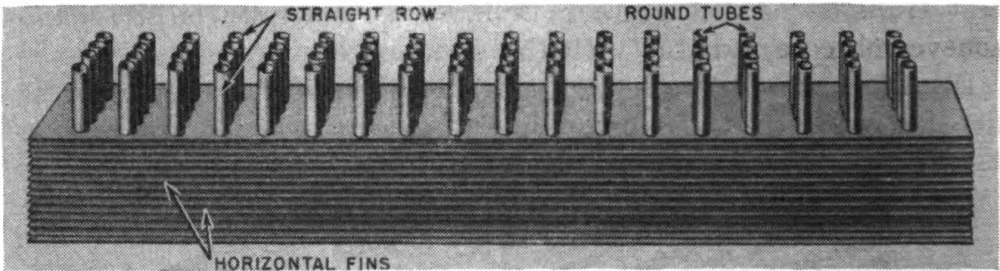


FIGURE 97.—Tubes in straight row.

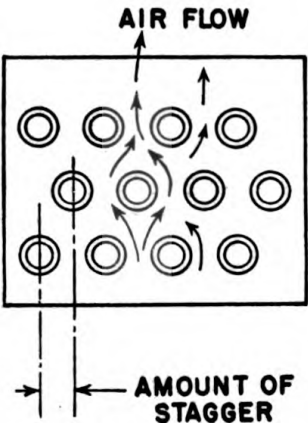


FIGURE 98.—Tubes in staggered row.

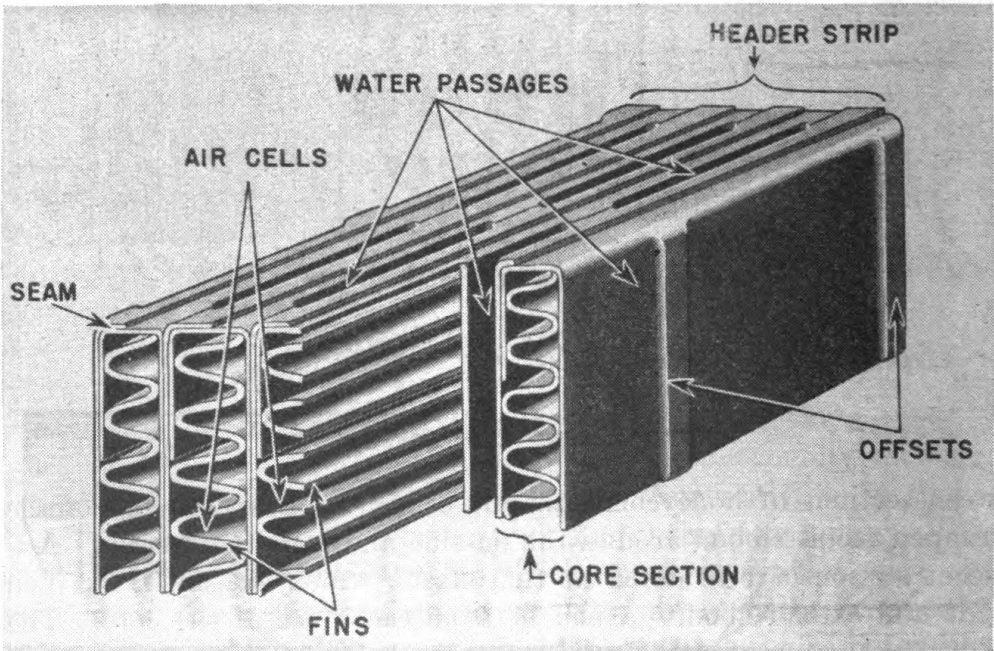


FIGURE 99.—Honeycomb core construction.

(b) Figure 99 shows how ribbons are overlapped forming a seam, to construct a single tube or section. Note that this seam, extending from the center of the header strip downward to span the side walls of three entire cells, provides a broad contact area to seal the ribbons. So many different-shaped air cells have been used in honeycomb core construction that it is impracticable to discuss them all. After learning to recognize a few representative types, the repairman should be able to analyze the construction of any other core.

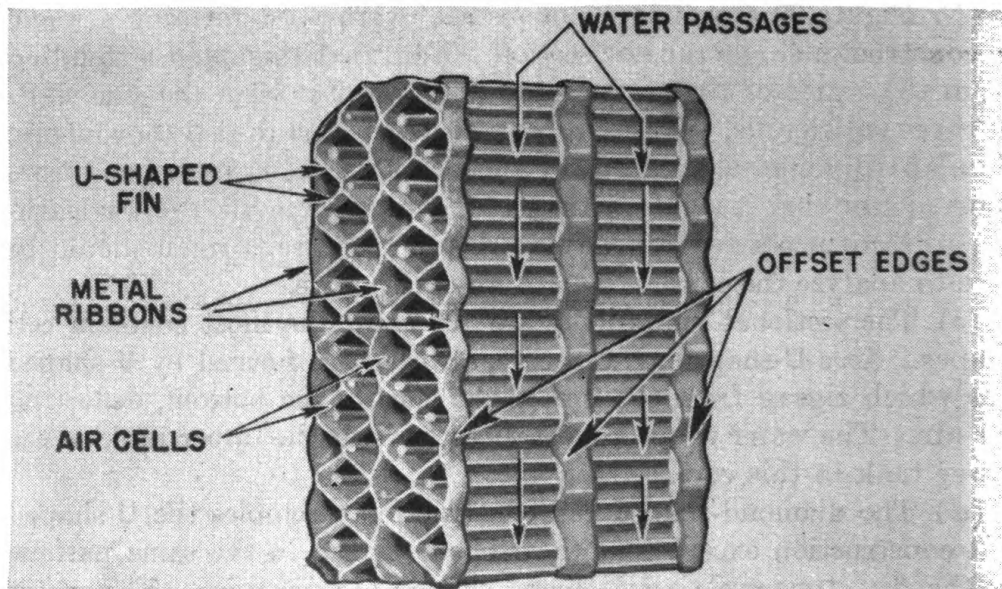
(c) The sectional views in figure 100 show the most common cell shapes. In a U-shaped air-cell core, air cells are formed by U-shaped fins which zigzag from the top of the core to the bottom, deflecting the air. The water drops almost directly from the upper tank to the lower tank in this core.

(d) The diamond-shaped cell construction resembles the U-shaped cell construction except that the ribbons zigzag in the same pattern as the fins, thus creating diamond-shaped air passages. The water passages between the ribbons are irregular and therefore more efficient in cooling, but more easily clogged. Each fin has many bumps and ridges, called deflectors, which increase the cooling area exposed to the air.

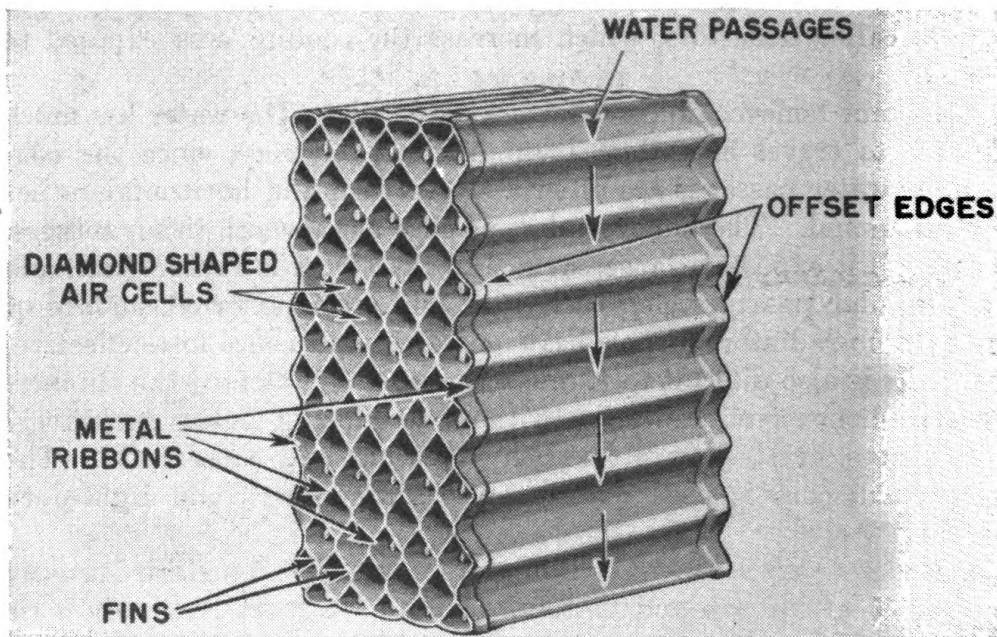
(e) Some honeycomb cores have square cells. The water has much farther to travel here than in a diamond-cell core, since the continuous water passages are alternately vertical and horizontal rather than diagonal. The honeycomb-type core has several disadvantages. Although it exposes a large surface to the air, it is rather frail, and its irregular passages clog easily. Much of the external surface of honeycomb radiators dispels heat indirectly and hence loses effectiveness. It is also difficult to manufacture metal ribbon of the thinness used in honeycomb radiators without producing holes, excessively thin places, or steel burs that may rust out and cause leaks. The honeycomb core is used mainly on passenger cars and light-duty trucks.

c. Radiator supports.—(1) Radiators in a motor vehicle are usually supported at the top and bottom. The top support is simply a tie rod extending to the cowl or cab front, whereas the lower supports are fastened to the side rails or to a strong cross member at the front of the chassis. Radiator mountings should prevent all twisting strains, road shocks, and engine vibration from reaching the radiator core, which at best is delicately constructed and easily damaged.

(2) The cast-type heavy-duty truck radiator shown in figure 93 has mounting brackets at the bottom of the side members, which are



① U-shaped air cell.



② Diamond-shaped air cell.

FIGURE 100.—Honeycomb core cell patterns.

bolted to the side rails of the chassis. Small springs (coil or flat leaf) or rubber blocks are placed between the brackets and side rails to cushion the radiator.

(3) Many radiators are housed in pressed metal shells. Fastened to the frame of the vehicle, the shell receives all the distorting forces

that the frame receives. A shell may be detachable from the radiator assembly or built in. It rests on a cross member of the frame, secured by studs and nuts, or is bracketed to side members, like the cast-type radiator. If the lower tank rests on the supporting member, soft pads of woven material, from $\frac{1}{8}$ to $\frac{3}{16}$ inch thick, are inserted to absorb road shocks.

(4) The radiator shell shown in figure 101 consists of a U-shaped steel band, which is bolted to the front cross member of the chassis

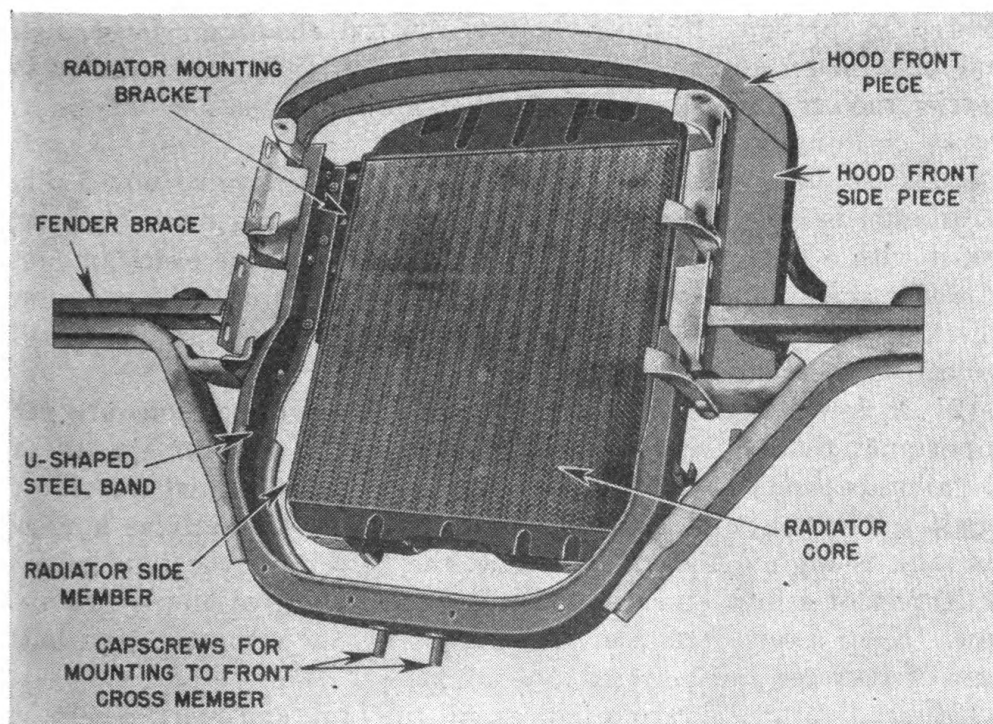


FIGURE 101.—Radiator in U-shaped shell.

frame by two capscrews. Brackets on the pressed steel side members of the core are bolted to corresponding brackets on the U-shaped shell, holding the radiator assembly rigidly, and greatly facilitating its removal for repairs. If the radiator is spot-welded and soldered to the mounting shell, the entire unit must be removed from vehicle before the core is accessible.

d. Radiator fittings.—The radiator fittings are the filler neck and inlet connection of the upper tank, and the outlet connection and drain valve of the lower tank. These are made of malleable iron or pressed metal. When they are manufactured as separate parts, they are brazed, soldered, bolted, or riveted to the tanks.

30. Radiator cleaning.—Radiator cleaning has three purposes: to restore perfect radiation, to facilitate soldering, and to remove obstructions to water circulation. Various chemical salts and dirt found in the water of different localities, together with grease and oil that find their way into the cooling system, collect inside the water passages of the radiator and insulate the water from the metal or stop circulation. This overheats the engine. Rust, disintegrated rubber hose, and accumulated deposits from antifreeze or stop-leak preparations will have the same effect. The water passages may be cleared by pressure flushing, boiling, or rod cleaning. Dust, lint, and bugs often adhere to the fin surfaces in sufficient quantity to restrict the air flow through the radiator and decrease its efficiency. Spray cleaning is then necessary.

a. Determining extent of clogging.—(1) To determine how badly a radiator is clogged without removing it from the motor vehicle, test it with a flow meter (fig. 102) which indicates the exact amount of water per minute that will flow by gravity through the radiator. Checking this reading against the flow rate of a new radiator will indicate the extent of clogging.

(2) A flow meter is easy to construct. Exact dimensions are not important; those given are merely suggestive. Set up a tank of 75-gallon capacity or more, high enough to be calibrated clearly at 5-gallon intervals, and attach a gage glass, approximately as long as the tank is high. A 2-inch valve at the bottom of the tank and 8 or 10 feet of 2-inch (inside diameter) hose will give ample gravity flow. Keep a set of reducer fittings nearby for connecting various sizes of radiator inlets.

(3) To obtain calibration figures, fill the tank and mark a zero at the water level near the top of the tank. Draw off exactly 5 gallons and make another mark on the tank. Continue until the tank is empty, making a mark near the gage for every successive 5 gallons that is run out.

(4) To test a radiator for clogging, first disconnect the lower radiator hose and plug this opening and the overflow pipe. Close the drain valve. Next fill the radiator with water to the top of the filler neck. Now, with the flow meter tank filled to the zero mark, remove the plug from the lower water outlet of the radiator and allow the water to flow freely from the radiator. At the same time, open the globe valve on the flow meter and keep the water flowing through the hose so that a constant level is maintained in the filler neck. Do not allow water to spill over. Time the flow at 1-minute intervals so that the flow meter calibration can be read in gallons per minute.

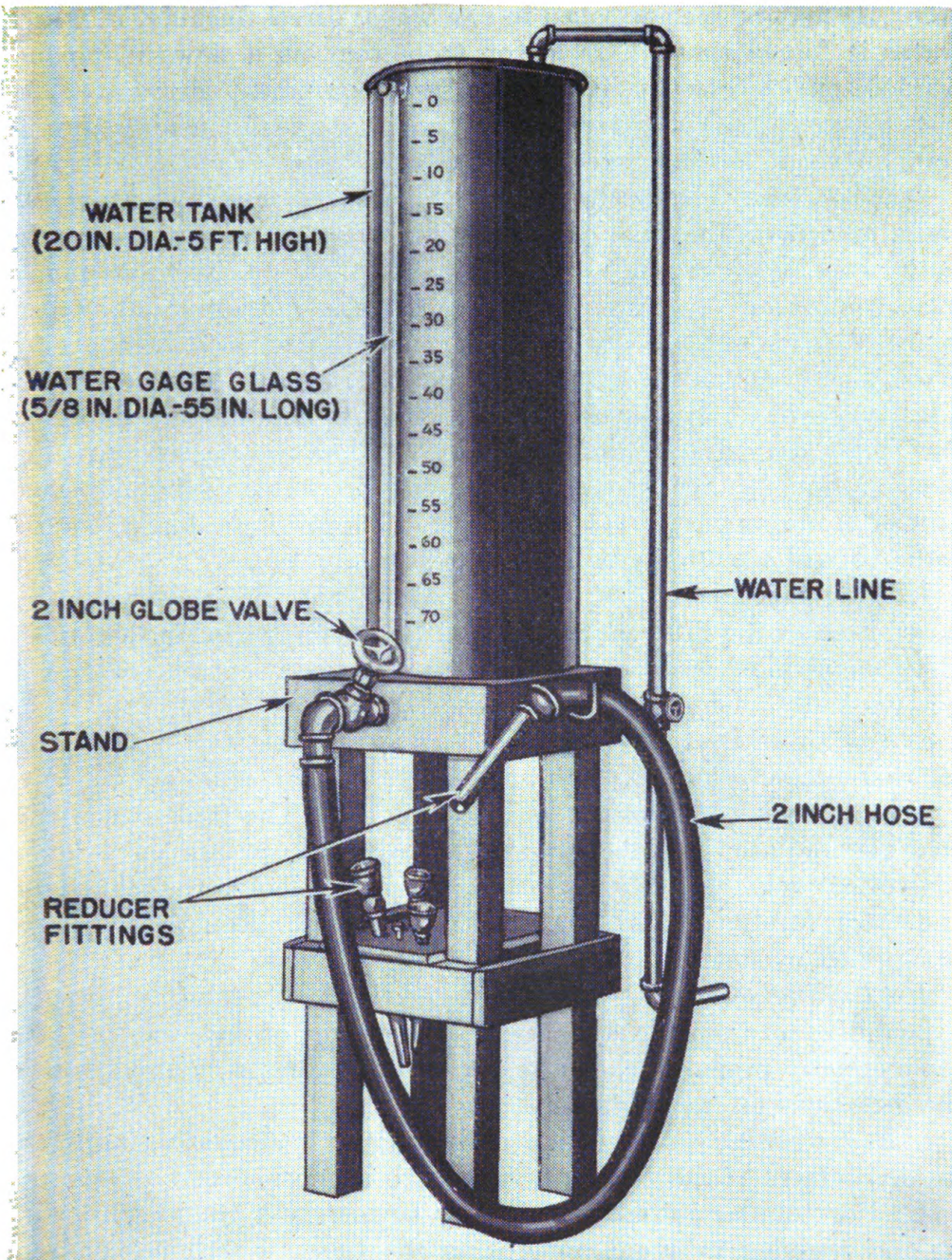


FIGURE 102.—Radiator flow meter.

This amount, compared to the manufacturer's standard figures, will indicate the amount of clogging, if any, and clearly demonstrate whether the radiator needs cleaning.

b. Pressure flushing.—Pressure flushing forces water by air pressure (approximately 5 pounds) through the water passages of the

core. It may be accomplished in two ways: direct flushing, in which water is forced through from top to bottom, as it flows in normal service; and reverse flushing. The same equipment is required for both methods: water pressure, air pressure, and a flushing gun to combine them, as illustrated in figure 104.

(1) To clean a radiator by direct pressure flushing, screw the radiator cap on the filler neck and attach a lead-away hose to the outlet connection of the lower tank. With the flushing gun in the inlet connection of the upper tank, fill the radiator with water. Since water alone is often insufficient to break loose the grease, sludge, rust, and scale within the radiator, it may be necessary to add some good radiator cleaner. When the deposits are loosened, turn the water off and admit compressed air to the radiator in short blasts, adding water between blasts until the water drains out clear and at a normal rate. The air must be applied gradually, as the radiator will stand only a limited pressure.

(2) Reverse flushing is similar, except that the lead-away hose is attached to the inlet connection and the flushing gun to the outlet. Both methods of pressure flushing are effective when the radiator is not too badly clogged.

c. Boiling out radiators.—Sediment so firmly packed in the radiator that pressure flushing will not remove it must be boiled out with a suitable chemical solution, as in figure 103. The tank is made so that the radiator may be lowered beneath the surface on a lever-controlled rack. Leave it there long enough to loosen the scale, rust, and other foreign matter, and then rinse it with clean water. Heat is supplied by steam pipes, a stove, or other means.

d. Cleaning solution.—To make a good cleaning solution, dissolve 1 pound of ordinary baking soda in 1 gallon of hot water. If a commercially prepared chemical cleaner for radiators is used, follow the directions on the container.

e. Rod cleaning.—If flushing or boiling is inadequate, scrape the inside surfaces of the water passages with a bristle brush or cleaning rod. For tubular radiators this may be merely a round wire with its end rounded to avoid puncturing the tube. For honeycomb or cellular radiators, use a flat strip of metal with edges and end rounded, not quite so wide as the water passage, pushing it back and forth through the water passages.

f. Spray cleaning.—Figure 104 requires the same equipment as pressure flushing. The spray of water under air pressure forces out dirt, bugs, lint, and other material lodged between the fins, so that free circulation of air around all parts of each tube and fin is restored.

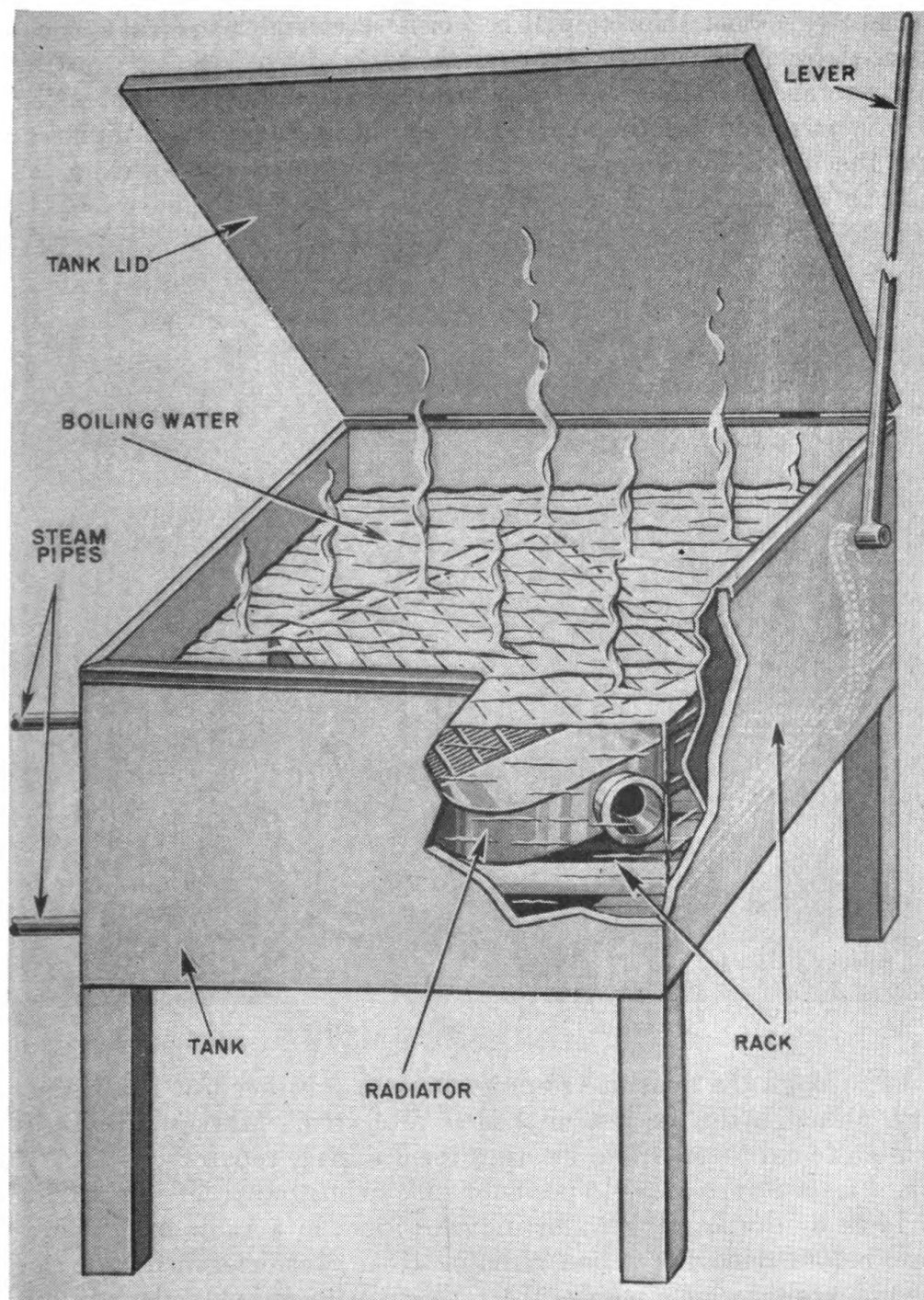


FIGURE 103.—Radiator boiling tank (cutaway view).

31. Testing radiator for leaks.—Before testing a radiator to locate leakage, inspect it carefully for visible leaks and solder them promptly, so that the test will be sensitive enough to reveal less obvious defects. There are two standard methods of testing: one by introducing air (under light pressure) into the radiator, immersing it in water, and locating the leaks by the appearance of bubbles; and the other, by filling the radiator with water and locating the

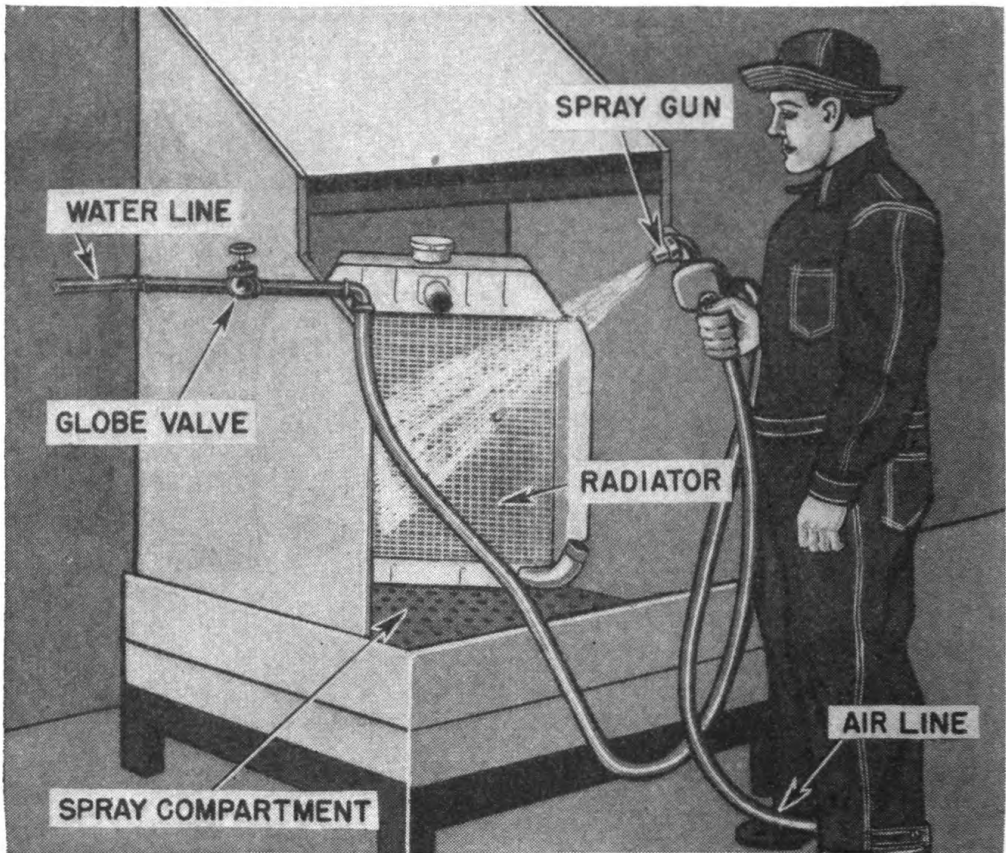


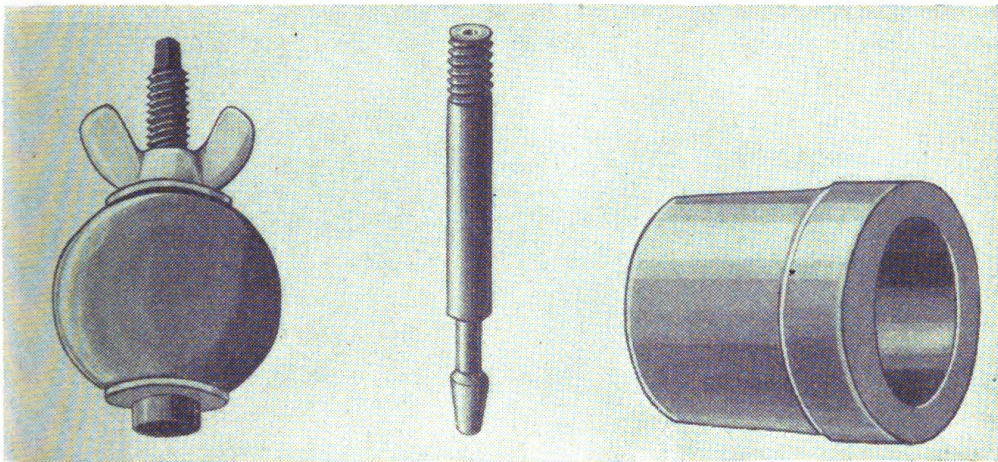
FIGURE 104.—Spray cleaning a radiator.

leaks through the moisture seeping through. Either test is satisfactory, although the air test method is preferred. Mark the leaks as soon as found to facilitate locating them during repairs.

a. Visual inspection.—Deposits of lime or magnesia left on outside surfaces by evaporating water indicate leaks in a radiator. Therefore, before removing a bad radiator from a vehicle, inspect it for these deposits, which enables the repairman to estimate the amount of repair needed. Although he can learn only by experience how to determine the true condition of a radiator from observation, he may be sure of one fact from the beginning—there are at least as many

leaks as he can see. Do not attempt to make an air or water test until all the leaks indicated by visual inspection have been repaired, for the effectiveness of these tests in discovering hidden leaks is lost when they reveal obvious leaks.

b. Air test.—(1) The air test, so called because leaks are indicated by escaping air, is the most efficient means of locating hidden leaks. Connect an air pressure tube directly or by a nipple (fig. 105) to the bottom of the overflow pipe. Screw the cap tightly on the filler neck and plug the inlet and outlet with expanding or cup-shaped rubber stoppers (fig. 105). Immerse the radiator in a testing tank, release the air, and trace the bubbles to their source.



① Expanding rubber stopper.

② Nipple.

③ Cup-shaped rubber stopper.

FIGURE 105.—Stoppers and nipple used for radiator testing.

(2) The most practical pressure for testing is from 3 to 5 pounds. Greater pressures easily damage the delicate construction of radiator cores. Frequently leaks will appear at low pressure, but not at high pressure, which closes the joints with accumulated lime and magnesia deposits or with expanded metal.

(3) Two air lines may be advantageously used when an automatic compressor is the source of air supply, one for soldering torches and one for testing. The air pressure system used by garages for tire inflation, consisting of a compressor, motor, pressure tank, gages, and reducing valves, is very satisfactory for radiator testing when the work is enough to keep several men busy. When no compressor is available, an ordinary tire pump will supply enough air pressure.

c. Testing bench.—(1) Since testing is a sloppy job, arrange the shop equipment systematically to minimize disorder. A very desirable testing bench for a permanent radiator repair shop is shown in figure

106. It can be easily constructed of lumber and lined with light-gage sheet metal to make it watertight. The water (test) tank is 4 feet square and 15 to 18 inches deep. This size will accommodate even the large radiators used on heavy duty trucks and tractors.

(2) The work bench, 4 feet wide by 6 feet long, is made in two parts. The section next to the water tank is a sheet-iron pan with a removable lattice rack placed on top of it. The bottom of the pan slopes gently to a drain having a screen which catches the loose solder as it falls from the radiator, and allows the water to flow away. As this pan

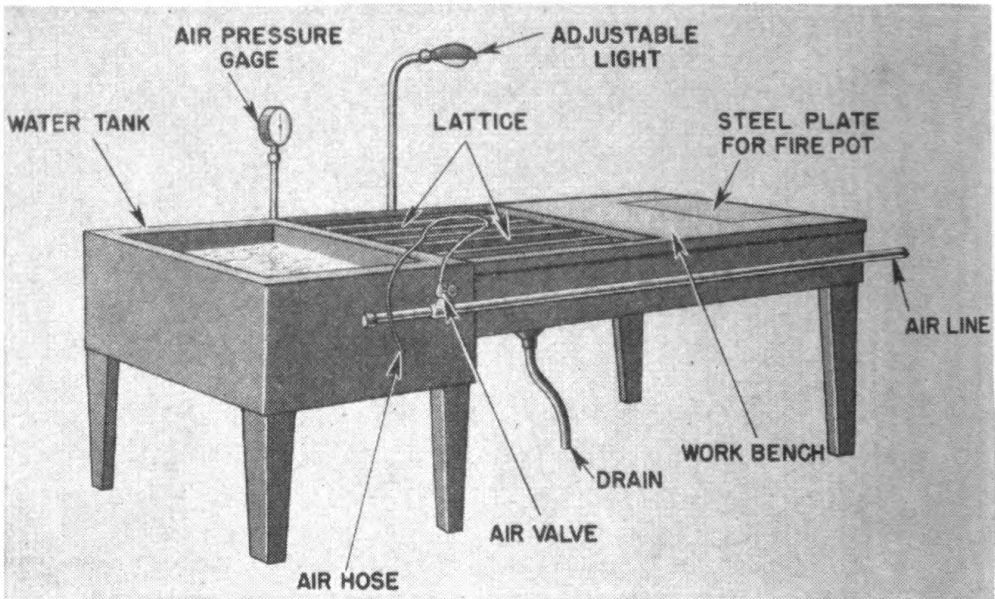


FIGURE 106.—Permanent bench for testing radiators.

becomes filled with solder, it is emptied and the solder reclaimed. The rest of the bench has a heavy top, on which the radiator may be placed for repairs.

(3) The testing bench should be placed near air pressure and water lines, preferably endwise to a wall under or just back of a window, to light the radiator adequately. An adjustable light as shown in figure 106 is very worthwhile. It should be fastened at the back of the bench so that it can be moved out over the water tank to provide sufficient light to see leaks. To prevent damaging the radiator by excessive air pressures, use an air pressure gage and be guided by it.

d. Field test tank.—For field service a collapsible canvas tank will be provided in the third echelon equipment unit set No. 1 for light maintenance companies. Figure 107 shows how this tank appears open and in use, and figure 108 shows it packed and ready for transport.

This tank consists of a one-piece canvas bag with wooden staves in pockets to hold the sides up and four round poles running through canvas loops to support the rim. A rubber mat protects the bottom of the tank from being torn by the radiator. When the tank is collapsed, two poles are removed and placed inside the tank, which is then rolled inside the mat and fastened with five flat metal hooks.

e. Locating leaks.—(1) Locating the leaks when bubbles rise is often difficult. Raise the radiator in the tank until the source of the bubbles is at the surface of the water. Locate as many large leaks as can

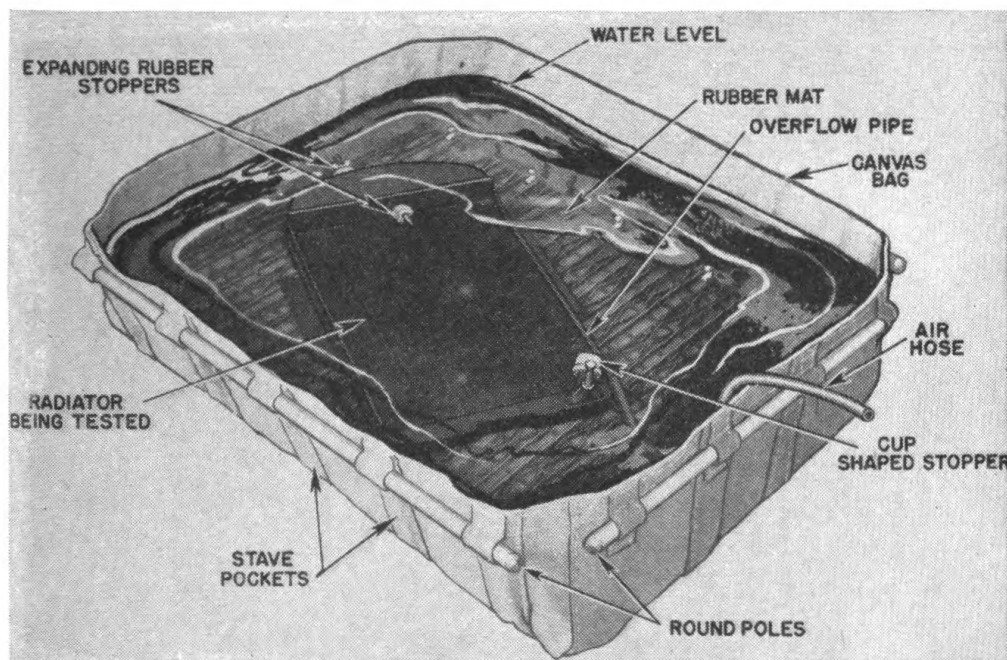


FIGURE 107.—Collapsible canvas tank, in use.

easily be found, drawing upon the knowledge of radiator construction; quite frequently the large ones can be detected more easily at a lower pressure. Repair these and retest for smaller ones. If water leaks in and remains for a later test, it may seal the compressed air from escaping and thus cause leaks in the bottom to remain undiscovered. On the last test, therefore, turn the radiator over in the tank.

(2) Two leaks occurring exactly opposite one another, one near the front of the core and the other at the back, should not be confusing. If testing a honeycomb core, stand it on edge, allowing the bubbles to come up the face; a tubular core should be raised until only the lower rows of tubes are immersed in the water. An accurate idea of the location of leaks is based upon a thorough understanding of core construction. To locate opened seams at the back of a tube, use a sharp pointed tool.

(3) To find very small leaks, place the bench light in back of the radiator so that the interior of the core can be seen. Stand the radiator on the bench and spread the supposed leak with flux or soapy water

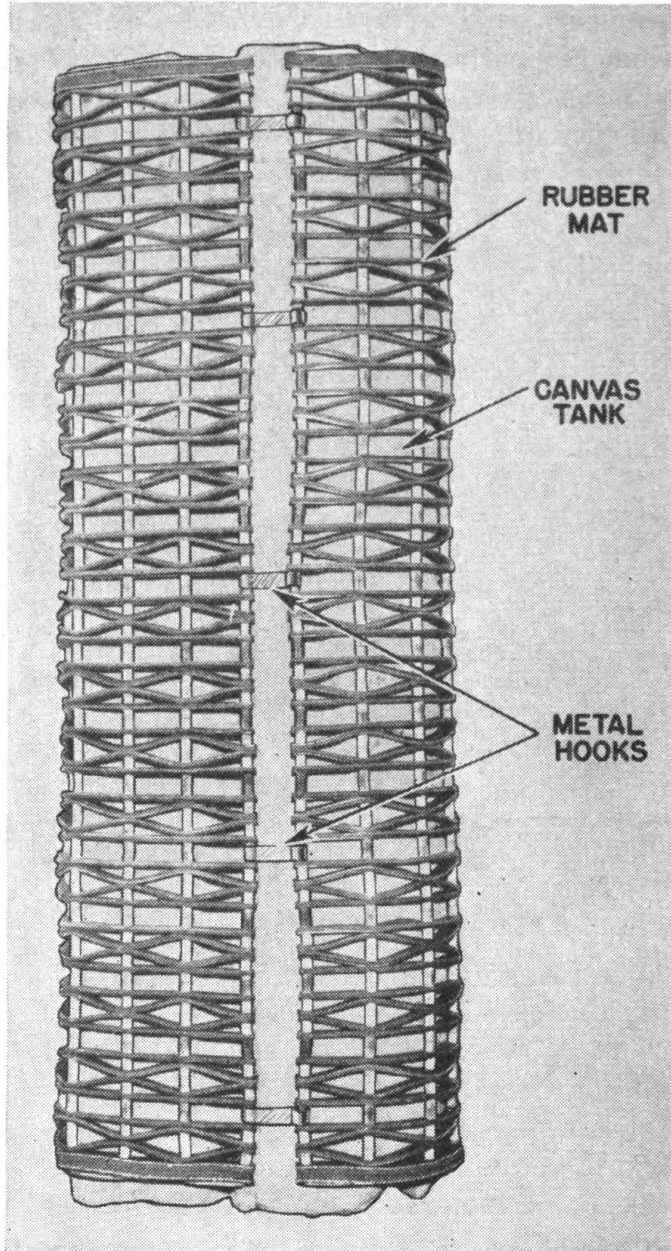


FIGURE 108.—Collapsible canvas tank, packed.

from an eyedropper, oilcan, acid brush, or swab. Compressed air seeping through the leak will cause the liquid to foam.

(4) As heavy truck cores frequently come to the repairman with water tanks removed, the water passages or tubes may have to be closed

before tests can be started. For a honeycomb core, solder dummy tanks to the header strips. These may be made of discarded tanks or plate metal, to one of which a tube has been soldered for the air hose. The tool shown in figure 109 for testing individual tubes is simply a cone-shaped rubber stopper with a $\frac{1}{4}$ -inch diameter hole at the large end, increasing abruptly to $\frac{1}{2}$ inch at the small end. A brass tube extends through the $\frac{1}{4}$ -inch opening to the beginning of the $\frac{1}{2}$ -inch hole. A washer soldered onto the brass tube prevents it from being pushed

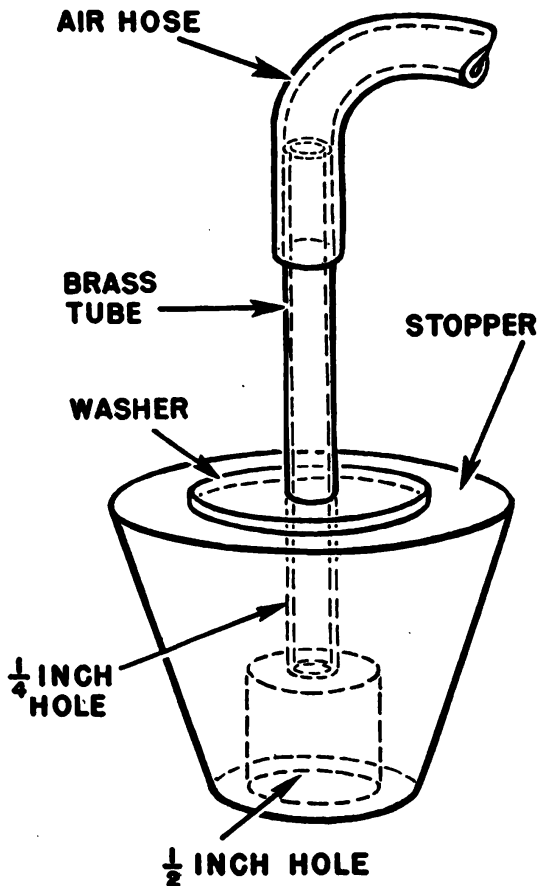


FIGURE 109.—Test tool for tubular cores.

in farther. The air hose is slipped over the tube. To use the test tool, submerge the core in a test tank, place the tool over one end of the tube to be tested, and allow the water in the tube to be blown out by the air pressure. Then, with the radiator level, close the opposite end of the tube with a finger. Bubbles will then appear wherever the tube leaks.

f. Water test.—The water test, so called because leaks are indicated by escaping water, replaces the air test when equipment is limited or supplements it when the air test is suspected of being inadequate.

Sediment and lime deposited about leaky joints may be forced into the joints by air pressure when the radiator is air tested, sealing the leak. A leak at the joint of tubes and header plates often refuses to show up under air pressure. For this reason, dry the radiator after repairing the leaks found by air pressure, and test by the water method. With the radiator thoroughly dry, remove the plug from the filler neck and fill the radiator with water, being careful not to run it over or spill on the outside. Examine the core carefully for leaks. Place the air hose over the lower end of the overflow tube and hold the palm of the hand over the filler neck, while a 5-pound pressure passes in against the water.

g. Marking leaks.—Adopt a uniform system of marking leaks, and remember it. For tank leaks a sharp pointed tool is most adaptable. For honeycomb cores bend a strip of tin or small wire like a clothespin and insert it, bent end first, at the leak. Let the one end of the "clothespin" project farther than the other to indicate which side of the cell is leaking.

32. Radiator failures.—Most radiator failures are caused by vibration, freezing, disintegration, strain, or collision. In tubular cores, worn or frozen tubes, broken solder between tubes and header plates, and cracked header plates are the most frequent causes of trouble. Honeycomb cores usually leak in the seams at either the soldered offsets or the header strips. Tank leaks are few. They may appear at unsoldered joints, cracked or worn spots, or fittings.

33. Removing and replacing overflow pipes.—If the overflow pipe leaks at the soldered upper-tank joint, heat it with the needle flame of a torch. When the solder becomes plastic, reach down into the filler neck with the fingers and push the pipe out past the tinned portion; then, from the outside, pull it free. If pulled first, it will probably break. Next clean, tin, and flux the end of the pipe, and insert it in the filler neck. Playing the flame on the joint, touch the pipe with a solder rod. When the solder begins to flow *into* the joint, remove the torch quickly and let the solder harden. Unless the fusing metal enters the joint, it will give little strength. Resolder the lower end of the overflow pipe securely to the lower tank or radiator side members, fastening it with clips where possible.

34. Repairing tanks and fittings.—*a. Procedure.*—(1) Honeycomb radiator tanks are soldered on core header strips, the solder usually extending about $\frac{1}{4}$ inch in from the edge. Vibration and the disintegration of solder make these joints leak.

(2) To remove the tank, melt the old solder with a torch and scrape the solder off with a wire brush or thin scraper. Then lay the radiator

flat on the bench and clean the joint with muriatic acid. After the joint has cooled, carefully pry the tank and core apart.

(3) Before replacing the tank, be sure to tin the surfaces of the joint. Then stand the radiator at an angle so that hot solder will not flow back into the water passages as the repairman holds a torch flame on the tank edge and flows solder along the entire joint. Do not apply too much heat. The full width of the joint edge should be sweat-soldered to the header strip of the core.

b. Patching cracked tank.—(1) Cracked radiator tanks must be patched; merely spreading solder over the crack will not make a permanently watertight repair. Scrape the surface an inch beyond each end of the crack and at least $\frac{1}{2}$ inch along each side if possible; dig down into the crack itself with a pointed tool. Flux and tin the cleaned surfaces, wiping them with a clean rag while the solder is still molten. Cut a patch of soft sheet brass about $1\frac{1}{2}$ inches longer and 1 inch wider than the crack, but not larger than the cleaned area. The patch preferably should be a little thicker than the tank metal. Brass is grained lengthwise of the original sheet; the grain of the patch should cross the crack when the patch is in place.

(2) Tin the patch and wipe it with a clean rag before the solder cools. Fit the patch in place as perfectly as possible, following the contours of the tank but avoiding bends. Rounded corners on a patch mark a careful repairman.

(3) When the fit is perfect, flux the tinned portion of the tank and both sides of the patch. With the patch in position, lay the tinned hot soldering copper on it, heating as wide an area as possible. If the patch is hot enough, a bar of solder can then be applied and the fusing metal will fill the entire space between the patch and the tank. It is not necessary to touch the tank with the soldering copper. Hold the patch in place steadily with a screw driver or other tool while the solder is setting. Apply only enough solder to cement the patch. After the solder cools, wipe away any surplus lumps with a hot copper.

c. Resoldering tank seam.—Stamped metal tanks are often made of metal pieces, lap-seamed at the bends. To open a leaky seam for resoldering, lay a well-heated copper on it with a little solder to conduct the heat. Now insert a piece of *rusty* sheet metal in the joint (solder will not adhere to rusty metal) and slip it along as the old solder is melted. When the joint is thus loosened well beyond the ends of the leak, pry the edges apart and scrape the surfaces. Tin at least one surface, holding the copper nearly vertical in the seam, and flux the inside of the seam. Then close the seam and seal it watertight with the soldering copper as shown in figure 110.

d. Resoldering fittings.—When the solder around the hose connections or filler neck is broken, remove the fitting with a torch and solder it with a copper. If a leaky hose connection is riveted to the tank, shear off the rivets with a chisel held flush against the surface, push them into the tank, and shake them out through the hose connection. Melt the old solder with a torch, placing the radiator on its side so that the fusing metal will flow away from the joint. Tap

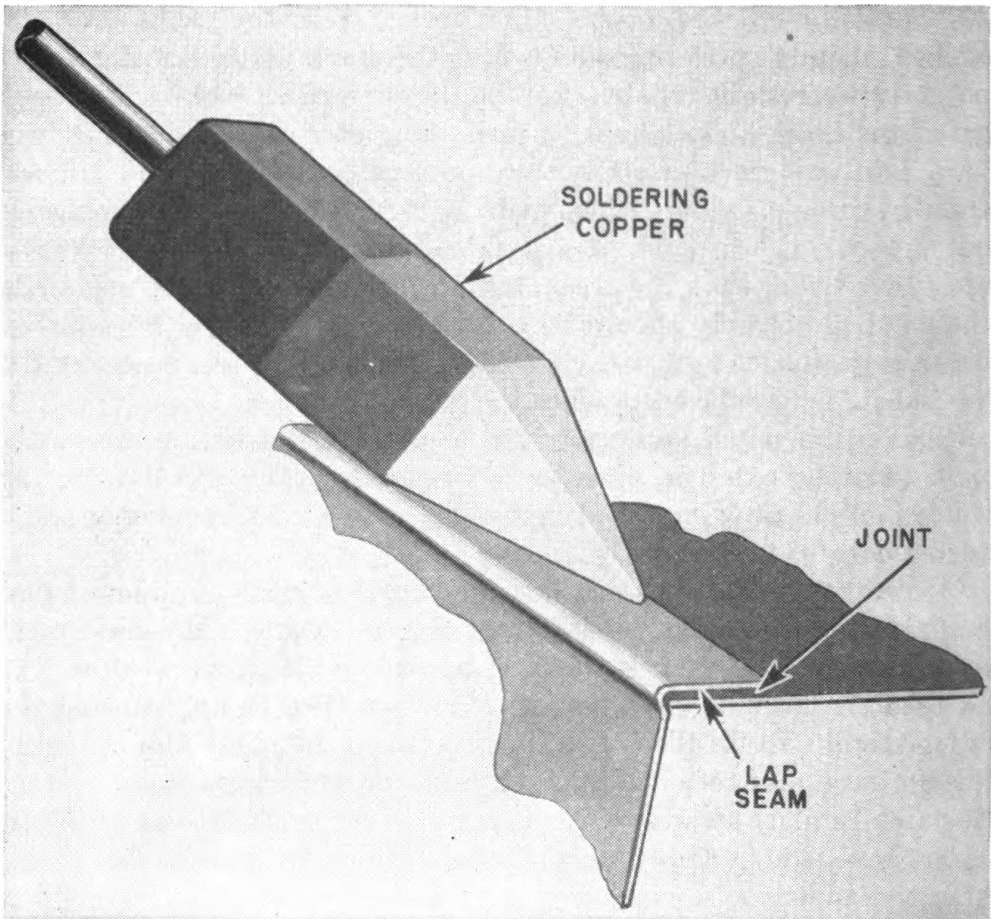


FIGURE 110.—Soldering tank seam.

the heated connection with a hammer to prevent the solder from re-setting as the flame is moved about the joint. Remove the fitting; clean, tin, and flux the surfaces; and resolder it to the tank, using brass replacement rivets well heated so that the solder will soak around them to form a watertight joint. If the leak is small, scrape and retin the outer surface of the joint; then cover it with a new layer of solder. This repair will hold if the fitting is well soldered at all other places.

e. Removing side members.—Removing side members of radiators that have pressed metal tanks is easily done with a torch. Melt and scrape away the old solder and pull the side members away from the tanks. Be sure the surfaces forming the joint are properly cleaned and tinned before resoldering.

35. Repairing frozen cores.—A badly frozen radiator should be cleaned with acid and boiled. Then stand the radiator on its side and examine it for opened seams in the water passages or tubes. Repair these and then apply the air or water test for leakage, as described in paragraph 31, to determine whether more seams must be soldered.

a. Resoldering face seam of honeycomb core.—Leaky water passage seams of a honeycomb core can be resoldered with a copper. These leaks usually occur where the fins are joined to the metal ribbons. After scraping away any lime or magnesia deposits, press the point of the hot soldering copper into the air cell against the water passage and pry it apart with a pointed scratcher or awl until reaching the binding solder. Then carefully scrape and tin the edges; close them with a pair of pliers (fig. 111), and flux and solder the seam. If the solder bubbles from moisture remaining in the joint, hold the copper on the face of the seam until the bubbling ceases. Spreading the solder from the face into the joints of metal ribbons and fins is slow but effective.

b. Soldering leaks in tubular core.—In figure 112, the fins have been cut and bent back to show a typical freeze in the seamless tubes of a tubular core. In soldering these leaks, press the edges back carefully so that the diameter of the tube is unchanged. Clean the damaged area and fill it with solder; straighten and paint the fins. The repair is not difficult if only a few tubes leak and the openings are visible, as then the fins probably will not have to be cut. Usually, however, there are a number of frozen tubes. If these are in a group, cut the fins at the center of the tubes with a pair of snips and pull out the pieces with nose pliers. When all the leaks are repaired solder false fins of very thin brass in their place.

c. Splicing tube.—(1) If a tubular radiator is so damaged that installing new tubes is not justified, splice the tubes. Saw the tube off above and below the damaged portion, and remove the fins or bend them out of the way to a point a little above and below the stubs. File the rough edges and scrub the inside of the stubs with a swab and muriatic acid. Cut a new piece of tube just the size of the piece removed, and notch one end, as in figure 113.

(2) To hold the repair tube in place, make two brass inserts, each $\frac{1}{2}$ inch long, of approximately 36-gage metal, and solder one of

them into a stub, with $\frac{1}{4}$ inch of the insert still projecting. Slip the other insert loosely into the notched end of the repair tube. Fit the other end of the repair tube over the soldered insert, with the notch outward, and work the loose insert part way into the stub with a pointed tool. Flux and solder the joints, filling the notch with

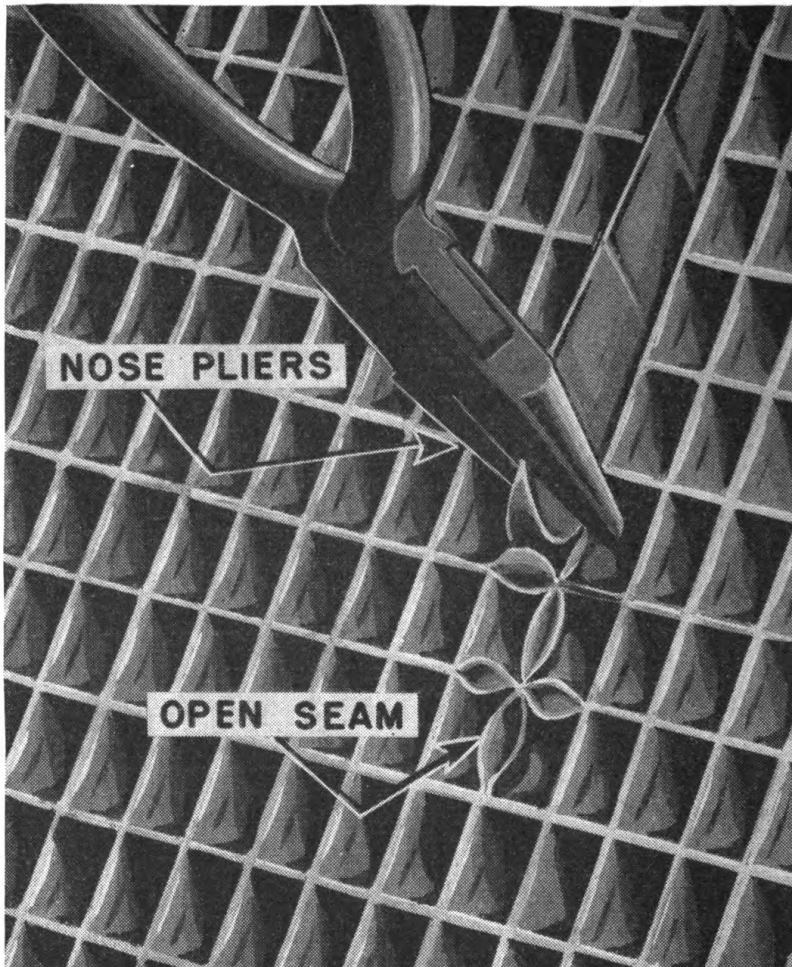


FIGURE 111.—Closing face seam of honeycomb core.

solder. Test for leaks, replace fins, and repaint. This repair defies detection if it is properly made.

(3) This splice is useful when tubes have been broken by vibration near the header plates. If this tube is ever frozen, it will break first at the joints of the splice, because the brass inserts reduce the size of the tube at these two points. Therefore, the smaller amount of water here is the first to freeze solid.

d. Cutting tube out of circulation.—Circulation through a tube that cannot be repaired may be blocked without marring the appearance

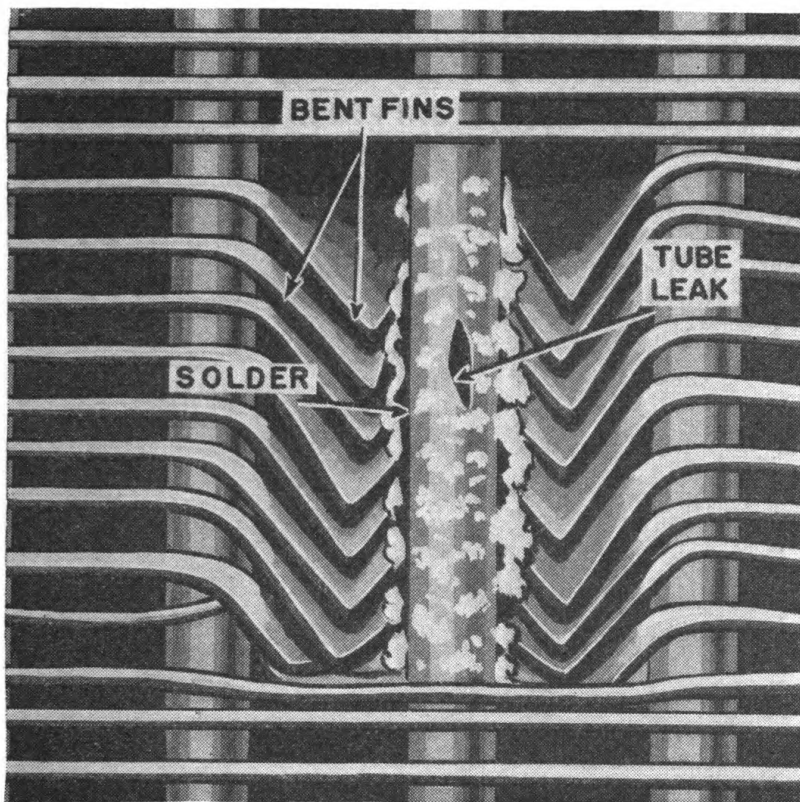


FIGURE 112.—Leak in frozen tubular core.

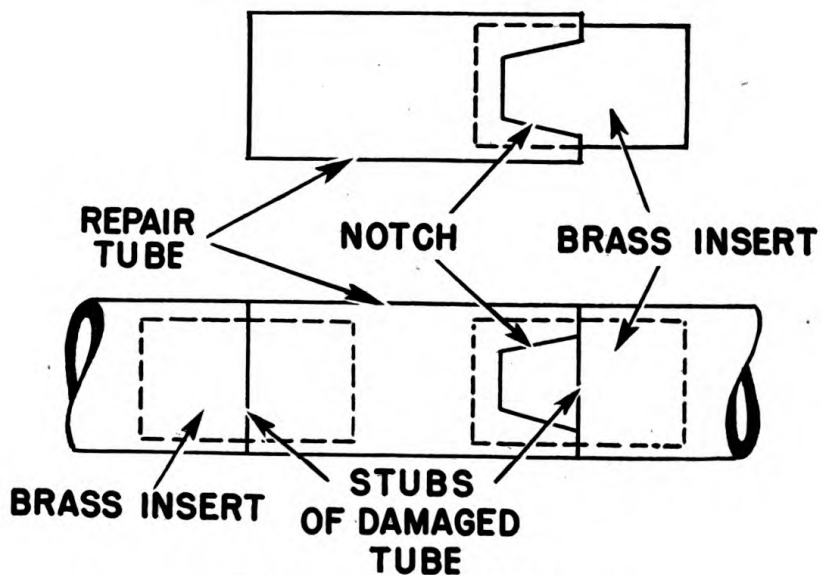


FIGURE 113.—Splicing damaged tube.

of the radiator. Cut a small oval piece from the side of the tube about $\frac{1}{4}$ inch from each tank, and scrape the inside of the tube clean. If the seam of the tube is not cut, care should be taken to scrape deeply enough into it to make a good solder joint possible. Raw muriatic acid may be used in cleaning, but it must be carefully removed afterward. Flux the inside of the tube. With a small pointed copper, flow enough solder into the tube to block the ends next to the

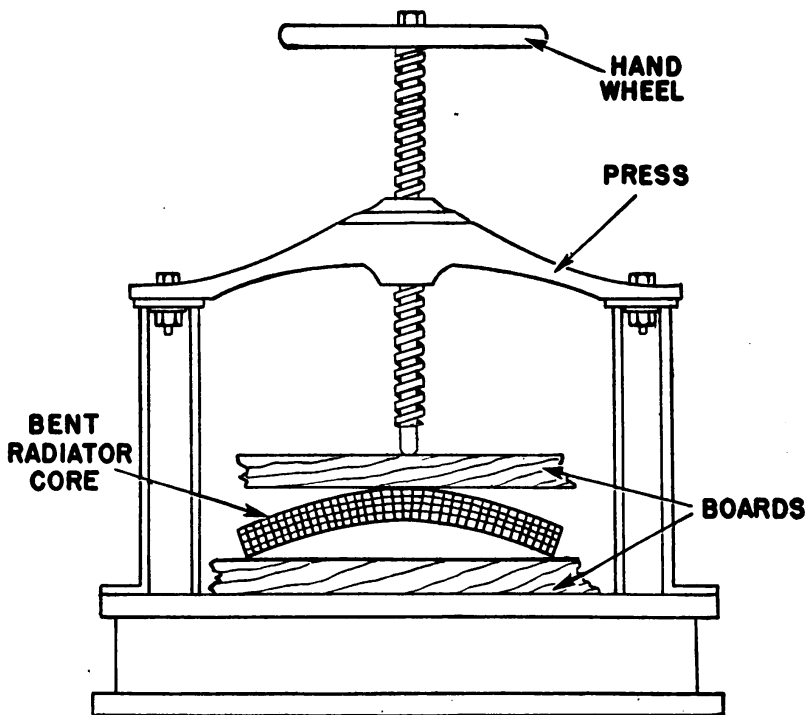


FIGURE 114.—Press for straightening radiator core.

tanks. Test the tube for leakage. If no leaks appear, reheat the copper and fill the hole to correspond nicely to the shape of the tube. When bent fins are straightened and the tube is painted, the repair is very difficult to detect.

36. Major core repairs.—a. Straightening.—(1) A bent radiator core can be straightened provided the bend is gradual, but not if it is so sharply kinked that the water tubes or passages are collapsed. Straightening is done best in a press, with boards above and below the core to spread the pressure and protect the air fins (fig. 114). If no press is available, place the core between boards on a flat surface and hammer the upper board to force the core back into proper shape.

(2) A core that has been slightly sprung by an impact at the side may be straightened in a simple frame such as that illustrated in

figure 115. Fit both clamps loosely on the core at top and bottom header strips with the lever in the position shown, and tighten the clamp bolts as far as they will go; then remove the core and repeat

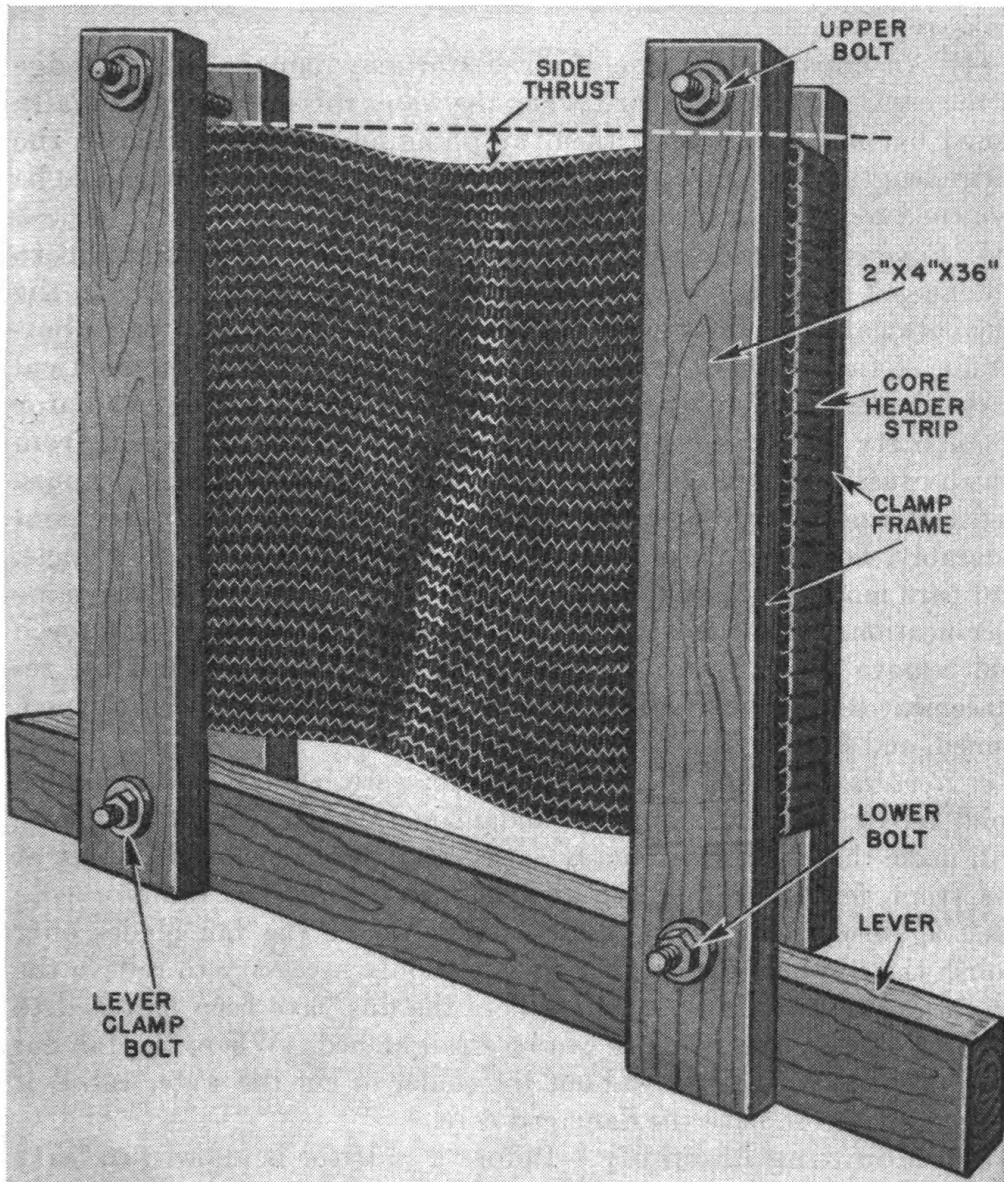


FIGURE 115.—Frame for straightening sprung core.

the operation with the clamps this time at each side of the core. This straightens the face of the core.

(3) This frame may be further used to straighten a side thrust in the core. The clamp to which the lever is attached should be secured on a bench and the core fastened in it with the high part of the thrust upward. Fasten the second clamp on the other end of the

core and raise the lever against the lower clamp bolt until the core is straightened. Removing the radiator tanks, as shown in figure 115, is not necessary unless the tanks are damaged. After a core has been straightened, the air fins must also be straightened and all leaks repaired.

(4) An impact at the side of a radiator may damage only the edge of the core. In a tubular core, when the water tubes are only partially closed but not torn, reopen them by plunging a blunt rod down the entire length of the tube. If the tubes are too severely damaged to be reopened by rodding, install a new core section.

b. Replacing core section.—If only a portion of a radiator core is damaged beyond repair, a section (fig. 99) can be replaced. In the conventional radiator, where water flows in the core from top to bottom, a section extends from top to bottom; it would be impractical to cut the sections horizontally to replace a part of the core. Radiator shops carry an assortment of scrap cores not totally damaged, from which usually may be obtained a section of the same height, thickness, and cell size as the core being repaired. Core dimensions vary considerably, however, from year to year and from vehicle to vehicle, and care must be taken so that a replacement section is of the same specifications as the damaged section. Melt the old solder with a torch and remove the defective section. Do not attempt to install the replacement section until all surfaces to be soldered have been cleaned, tinned, and fluxed.

c. Recoring.—When the entire radiator core has been damaged beyond repair, but the tanks are undamaged, substituting a new core will make the repaired assembly as serviceable as new. An impact at the front fender or radiator assembly may force the radiator core back against the revolving fan blades. Where the fan blades only polish the edges of the core air fins, it is only necessary to relieve the brightness with a little paint. Where the fins have been flattened to close up the air cells, the fins can be straightened. Where the fan cut is so deep that it has gouged out the solder or cut the water tubes, it is necessary to replace the damaged core.

37. Mounting assembly.—Before a radiator is allowed to leave the shop, its support, whether connected directly to the radiator or to the shell, should be able to carry it properly. If a soldered shell has worked loose, resolder it. If the shell is bolted to the core channels, solder them rigidly to the tanks and straighten or brace them so that they will not become loosened and allow the radiator to be worn or shaken to pieces. Reinforce the top support rod connection to withstand the thrust or pull at this point. The permanency of a repair reflects to the credit of the repairman.

APPENDIX

BIBLIOGRAPHY

The following sources have been consulted for illustrations and text material in the preparation of this manual. As they contain more detailed information on sheet metal work, body, fender, and radiator repairs than is contained here, consult them for collateral reading.

Chilton Body and Frame Manual (Philadelphia, Pennsylvania: Chilton Co., published annually).

Curfman, F. L., and Leet, T. H., *Manual of Automotive Radiator Construction and Repair* (Maryville, Missouri: F. L. Curfman Manufacturing Co., 1921).

Horine, M. C., *Chassis Overhauling and Repairing* (Scranton, Pennsylvania: International Textbook Co., 1932).

Hurley, Clarence C., "Turret Top Replacement," *Motor Service Magazine* (July 15, 1940, p. 36).

Packer, C. E., *Automotive Body and Fender Repairs* (Chicago, Illinois: The Goodheart-Willcox Co., 1939).

Packer, C. E., and Ahlers, J. A., *Service Shop Management* (Chicago, Illinois: American Technical Society, 1934).

"Paddle Soldering," *Motor Service Magazine* (September 16, 1940, p. 59).

"Radiator Care (Fall and Spring)," *Motor Service Magazine* (November 15, 1938, p. 44).

Sargent, Frank T., "Metal Finishing," *Motor Service Magazine* (November 15, 1940, p. 36).

Sargent, Frank T., "Sheet Metal Repairing," *Motor Service Magazine* (August 15, 1940, p. 38).

Sargent, Frank T., *The Key to Metal Bumping* (Cleveland, Ohio: The Fairmount Tool and Forging Co., 1939).

Sargent, Frank T., "Torch Soldering," *Motor Service Magazine* (February 15, 1941, p. 52).

"Spring Radiator Work Is Worth Getting," *Motor Service Magazine* (April 15, 1941, p. 92).

QUARTERMASTER CORPS

Yates, Raymond F., *Soldering and Brazing* (New York, New York: Norman W. Henley Publishing Co., 1925).

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(For explanation of symbols see FM 21-6.)

